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GRASS CULTURE AND RANGE
IMPROVEMENT IN THE CENTRAL
AND SOUTHERN GREAT PLAINS

By

D. A. SAVAGE

Agronomist

Division of Forage Crops and Diseases
Bureau of Plant Industry





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By D. A. SAVAGE,² *agronomist, Division of Forage Crops and Diseases, Bureau of Plant Industry*

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INTRODUCTION

The purpose of this circular is to present in condensed form for handy reference the best available information on two important questions pertaining to grass culture and range improvement in the central and southern Great Plains: (1) How may pasture grasses be reestablished on cultivated land, and (2) how may grasses be restored and maintained on depleted pastures? The value of the circular lies in the suggestions it contains. It is not conclusive and, because of a dearth of facts, it could not be made so.

The information presented is taken from many different sources. Publications issued during the last 50 years have been reviewed. Unpublished experimental data have been considered. But one of the

¹ Cooperative investigations of the Division of Forage Crops and Diseases and the Division of Dry Land Agriculture, Bureau of Plant Industry, U. S. Department of Agriculture.

² The writer gratefully acknowledges the helpful assistance of many State and Federal officials who informally provided much valuable information incorporated in this report and helpfully reviewed the manuscript. He is also indebted to L. F. Locke and E. W. Johnson, Division of Dry Land Agriculture, Bureau of Plant Industry, for providing most of the illustrations.

richest sources of information has been the exchange of observations among various students of Plains agriculture whose experiences extend over the last 30 years.

The recognized dearth of factual data on grasses and revegetation practices in the central and southern Great Plains is a direct outgrowth of shifting public sentiment with respect to land use policies in that region. Nearly 50 years ago the United States Department of Agriculture undertook comprehensive studies of these problems and for a few years conducted research which, had it continued, would have yielded an abundance of data of the kind now generally in demand. Unfortunately, however, public interest in cultivated crop culture discouraged grass research and resulted in its discontinuance. Only within the last few years has public sentiment shifted back to grass to a degree that has made possible a renewed research attack upon the problems involved in the regrassing of cultivated farm land and the restoration and maintenance of grass cover on depleted ranges.

REESTABLISHING PASTURE GRASSES ON CULTIVATED LAND

Cultivated land may be abandoned farm land, or it may constitute those parts of currently operated farms on which the operators desire to reestablish grass. In either case it is desirable to consider (1) natural and (2) artificial methods of revegetation.

NATURAL REVEGETATION

What may be expected from natural revegetation of cultivated land is indicated by the results of a survey made in 1936³ (60).⁴ During that survey chartographs were made of the basal cover occupied by 124 species of grass and 448 species of forbs (weeds), sedges (grass-like plants), and shrubs, on 167 abandoned fields and 138 adjacent virgin pastures, on different textures of soil and under different grazing treatments near Woodward, Okla.; Dalhart, Tex.; Tucumcari, N. Mex.; Springfield, Akron, and Colorado Springs, Colo.; Garden City, Tribune, Hays, and Colby, Kans.; and North Platte, Nebr.

The results of that survey show that the length of time required for the more desirable grasses fully to recover abandoned fields varies on the average from 25 to 40 or more years, depending upon environmental conditions. These results verify in a large measure previous reports by Shantz (61), Clements (13), Clements and Chaney (15), and Clarke and Tisdale (12). E. W. Nelson, in charge, Department of Range and Pasture Management, Colorado State College, Fort Collins, Colo., recently reported informally that still longer periods were required for the natural reclamation of abandoned land in northeastern Colorado.

The 1936 survey showed that very few fields reverted to an optimum stand of the more desirable species in less than 25 years and many required more than 40 years (fig. 1). Although many of the fields were reclaimed with weedy-type grasses early in the stage of

³ SAVAGE, D. A., and RUNYON, H. EVERETT. IMPORTANT PLANT SPECIES ENCOUNTERED ON PASTURES AND ABANDONED FARM LAND IN THE CENTRAL AND SOUTHERN GREAT PLAINS IN 1935 AND 1936. U. S. Bur. Plant Indus. Multilith Pub., 19 pp. 1937.

⁴ Italic numbers in parentheses refer to Literature Cited, p. 50.

abandonment and many became fully covered with good grass during the periods indicated, none of the fields repossessed a cover comparable in composition with the disclimax vegetation present on adjacent

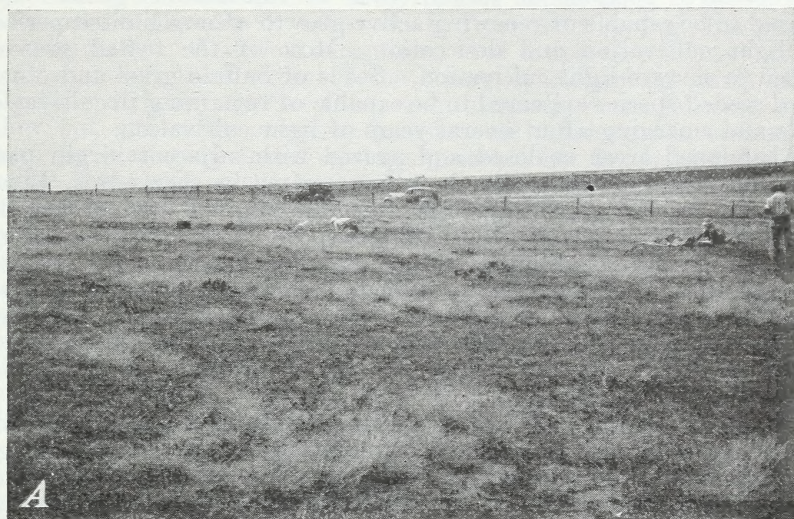


FIGURE 1.—Charting vegetation on a field near Akron, Colo., that had been cultivated 6 years, abandoned 43 years, and heavily grazed: A, View showing persistence of tufted red three-awn (triple-awn); B, close-up showing typical mat of ringgrass, an indicator of close grazing or other disturbance.

virgin pastures. The extreme slowness with which blue grama⁵ and many of the taller grasses became reestablished was responsible for this qualitative condition of the vegetation on abandoned areas.

Vegetative portions of stoloniferous or rhizomatous grasses appeared to be capable of renewing active growth after a limited period of light cultivation and desiccation. Most of the tufted grasses failed to survive light cultivation. Seeds of buffalo grass and other hard-seeded species appeared to be capable of remaining in cultivated soils and emerging after several years of light cultivation.

Abandoned areas enclosed and grazed with adjacent virgin pastures recovered more rapidly than those grazed by themselves. Livestock apparently were helpful in disseminating the seed of buffalo grass, since numerous seedlings of this species were noted emerging from the droppings of cattle. Grazing, unless extreme, also favored the spread of buffalo grass by reducing the shade and competitive effect of weeds and taller grasses. Other species, however, were delayed in recovery by close grazing of fields and adjacent pastures, which reduced seed production, hampered seedling survival, and promoted soil blowing.

The proximity of tilled fields and the resultant damage from soil blowing greatly delayed recovery in many instances. Much damage resulted from the smothering effect of wind-deposited silt. The scarifying action of dust-laden winds seriously contributed to the death of many pasture plants in the region. Small pastures, often wholly surrounded by cultivated fields, suffered more injury than large areas.

Damage from soil blowing usually was more noticeable on sandy soils than on soils of heavier texture, but recovery on the sand, when protected from excessive grazing and wind erosion, was more rapid than on the heavier soils. Recovery on sandy areas was not only delayed by soil blowing but also by the absence of stoloniferous species and the scarcity of rhizomatous species. Under certain conditions blowout grass, prairie sandgrass (sand reedgrass), and giant reedgrass had rhizomatically stabilized active dunes and were being gradually replaced by more palatable species. Cultivation, abandonment, and eventual reestablishment of grasses on sandy soils resulted in satisfactory control of sand sagebrush and other undesirable weedy shrubs, leaving many abandoned fields with a cover superior to adjacent untilled pastures. Reporting on similar results in Canada, Clarke and Tisdale (12) stated that when a good stand was obtained on an abandoned field it was much more productive than the native sod.

On all soils succession of growth on abandoned fields assumed four rather distinct but overlapping stages. These are listed in order of dominance within each group: (1) Annual weeds and annual grasses; (2) the less palatable short-lived perennial grasses, and biennial and perennial forbs; (3) short-lived perennial grasses, perennial forbs, and a few long-lived perennial grasses; (4) dominant and secondary perennial grasses, accompanied by varying quantities of other plant species, depending on environmental conditions.

Sand dropseed, red three-awn, and bluestem (western wheatgrass) were usually the first perennial grasses to become established on aban-

⁵ The scientific names, accredited common names, and locally recognized and other synonyms for this and other grasses mentioned are listed in the Appendix, p. 54.

doned land. The latter species was less important at lower altitudes and in the Southern Plains than elsewhere in the region. Frederic E. Clements, of the Carnegie Institution of Washington, reports informally that this species rarely if ever enters early in abandoned fields unless plantlets or rootstalks had persisted through the period of cultivation. With few exceptions, sand dropseed was more active and abundant than either of the others in reclaiming sandy soils. On soils of heavy texture these species usually were followed by a slow but ultimately complete invasion of buffalo grass, and much later by scattering traces of blue grama. On the lighter but not active dune soils sand dropseed was often followed soon by sand paspalum, and later by side-oats grama, hairy grama, switchgrass, prairie beardgrass (little bluestem), and turkeyfoot (sand bluestem). Often blowout grass, prairie sandgrass (sand reedgrass), and giant reedgrass, particularly blowout grass, were the first grass species to invade active sand dunes and, after stabilizing such areas, were gradually replaced by many of the other species listed above. Blue grama was ordinarily the last species to become established and in no place, except on fields grazed only in the winter near Colorado Springs, was it an important agent in natural recovery.

On the heavier soils abandoned fields finally became covered with a nearly pure stand of buffalo grass, accompanied by very little blue grama. Under similar conditions adjacent virgin pastures usually contained a disclimax mixture of these species in nearly equal amounts. Abandoned fields fully covered with buffalo grass survived the recent drought with much thicker stands and appeared to be more productive than adjacent virgin pastures similarly grazed. The residual effect of earlier cultivation in making the soil more receptive to moisture may have been partly responsible for these advantages. It is possible that the earlier cultivation had removed the competition of the deeper-rooted forbs.

These results indicate that it is important that only light or deferred grazing be permitted during the early stages of recovery after abandonment for all species except buffalo grass which will endure heavier grazing (58, 59). The slowness with which blue grama reclaims abandoned fields unassisted indicates that a thin stand of this species may not be expected to thicken very fast without considerable protection from grazing and may require special care in establishment to increase seed production and facilitate seedling survival. Buffalo grass, on the other hand, reseeds itself more readily, and, being stoloniferous, usually spreads a foot or more each season.

Natural revegetation of cultivated land may be expected to proceed at much slower rates in the future than in the past, because fewer seeds and seed-producing plants are available on adjacent areas. Less land is in grass than formerly and most pastures are severely damaged or practically denuded of vegetation. A reserve of grass seed was present on the surface of many pastures at the beginning of the recent drought and many seeds germinated following the first rains, but practically all of the seedlings died during recurrent periods of dry weather. Each interval of relief from drought witnessed the appearance of successively fewer seedlings, most of which met the same fate as the first, resulting in exhaustion of seed reserves.

ARTIFICIAL RESEEDING

Nature's slow methods of reclaiming abandoned land may be greatly improved and hastened by artificial methods based on thorough knowledge of the natural spreading habits of the adapted species, and by taking full advantage of favorable moisture conditions. These statements are supported by the reports of Hanson (31), Nelson (46), Williams (72, 73), Wilson (74), and Wooton (75).

PREPARATION FOR SPRING SEEDING

Where the land is subject to severe erosion, it may be advisable to construct terraces or contour furrows as the first operation in preparing for grass seedings.

Optimum conditions desired in a seedbed for grass include plentiful supplies of surface and subsoil moisture, fine, firm soil, and sufficient noncompetitive surface residue from previous crops to control soil blowing and reduce surface evaporation. This ideal combination of conditions is difficult and often impossible to obtain in blow regions. Summer fallow is usually dependable in providing the subsurface moisture, but is seldom safe because of its susceptibility to wind erosion. Since stands of grass can be established throughout most of the region only after minimizing the hazard of wind erosion, it seems advisable first to grow a close-drilled crop of Sudan grass or sorghum. Although these crops may exhaust the subsoil moisture, their stubble serves to reduce wind erosion and retards rapid drying of the surface soil. Current precipitation after the Sudan grass or sorghum crop has stopped growth may or may not be sufficient to provide the necessary moisture, but this risk must be taken. Except under especially favorable moisture conditions, failure is almost certain to result from grass seedings on land not protected by stubble or special tillage.

Sudan grass usually is preferred to kafir, sorgo, milo, and other sorghums as a preparation for seeding perennial pasture grasses the following spring. Sudan grass often recovers faster and more completely from mowing or grazing, tillers more freely at the base, and leaves a denser stubble than other sorghums, although seed of the others is often cheaper. If sorghum is used, it probably should be sown at rates varying from 30 to 50 pounds per acre. A satisfactory seeding rate for Sudan grass ranges from 15 to 20 pounds to the acre. These preparatory crops are more certain to provide a satisfactory stubble cover when sown in May or June than later in the year.

Sudan grass may be drilled on smooth, clean land in the ordinary manner. Where a rough surface is desired for the control of run-off and erosion, drilling on the contour on terraced or nonterraced sloping land or at right angles to the prevailing wind direction on level land would undoubtedly result in improved growth of the preparatory crop and of the subsequently seeded grasses. Land prepared in advance by solid furrowing on the contour, with a basin lister or ordinary lister, may be sown to the preparatory crop by drilling parallel with the furrows. This will tear down and somewhat level the ridges but leave the land sufficiently rough to facili-

tate the penetration of moisture. The Sudan grass may not germinate quite so completely or so uniformly as on smooth land, but should emerge sufficiently to provide satisfactory protection for grasses sown the following year. This method may be modified and further improved by sowing the Sudan grass or sorghum in strips, leaving a lister furrow unseeded and undisturbed between drill widths. The entire area may then be sown with grasses the following year. On heavy soils, buffalo grass sods may be placed at intervals in the furrows. The result would be a deep furrow with a series of smaller intervening furrows, which would control run-off and erosion under ordinary conditions.

Where the land is level or very sandy and not inclined to lose water readily by run-off, the blank listing operation may be dispensed with and a series of smaller furrows obtained at less expense by seeding the Sudan grass in 14- to 20-inch drill rows with one of the new furrow-type grain drills. This operation, as well as the blank listing just before drilling the Sudan grass, may require one or more light cultivations in advance to control weeds and store moisture. Planting the preparatory crop in wide-spaced lister rows is not advisable, because the resultant stubble is seldom sufficient to control soil blowing and retard surface evaporation while the grass seedlings are becoming established the following spring.

It appears essential to cut the Sudan grass or sorghum crop so as to leave stubble about 8 to 12 inches high. If this is done before the crop has approached maturity, the aftermath usually produces more vigorous basal growth. This adds to the wind-resisting and evaporation-reducing qualities of the surface residue the following spring. In this region practically every rain is followed by high winds, which often dry the surface soil before the shallow-seeded grasses have time to emerge and become well established. High, dense stubble helps to keep the surface soil moist a day or two longer than on bare fallow land. This delay in evaporation often represents the difference between success and failure in obtaining satisfactory initial stands.

Preliminary data indicate that to leave the Sudan grass or sorghum crop unmowed not only wastes valuable forage but results in the production of less basal growth than when the crop is mowed early and high. Furthermore, unmowed plants often break off at the base and blow away during the winter. When Sudan grass is allowed to mature, volunteer plants often appear the following spring and offer severe competition to the slower growing perennial grasses.

A few instances have occurred where small areas of high-cut stubble, nearly or wholly surrounded by cultivated fields, have become too deeply covered with wind-deposited silt to provide a satisfactory seedbed. Close mowing of the stubble on isolated areas of this kind would reduce the deposit of silt but leave a poor seedbed. It is desirable, therefore, that surrounding areas be at least temporarily stabilized before an attempt is made to reestablish grass on cultivated land.

Close-drilled stubble has other advantages as preparation for grass. The soil is usually firmer, cleaner, and freer of weeds than on land without stubble.

Under ideal moisture conditions Sudan grass may be drilled in late summer on fallow land. The objectives of this plan are to seed the Sudan grass early enough to provide the required cover and late enough not to exhaust the subsoil moisture provided by summer tillage. This condition is extremely difficult to attain. Often the late summer rains are not sufficient to promote prompt germination and growth of the Sudan grass. Occasionally an early frost kills it before growth is sufficient for the purpose intended. Furthermore, a late frost may enable the fall-grown grass to continue growth and leave the soil nearly as dry as if it had been sown in the spring.

PREPARATION FOR FALL SEEDING

The foregoing suggestions are based largely on the assumption that the pasture grasses are to be sown in the spring. It is more difficult to suggest methods of preparing weed-free seedbeds containing noncompetitive stubble material for fall seedings. Stubble fields of small grains are usually lacking in subsoil moisture and usually become infested with weeds and volunteer growth which offer detrimental competition to fall-sown grasses. Summer-fallowed land is less apt to blow in late summer and early fall than in the spring, but the danger of blowing is usually too great to risk this method at any season of the year, although it has been successful at Woodward when the land was listed at intervals of 7 feet to control blowing. Seeding winter wheat or winter rye late in the spring may offer some possibilities as a preparation for fall-sown grasses. These preparatory crops, when sown after frosts in the spring, usually grow in a rather dense, prostrate manner and die before late summer, leaving a cover more conducive to the control of wind erosion and the conservation of subsoil moisture than if sown the previous fall.

Surface tillage may be necessary to control weeds in advance of seeding. This operation should be performed at shallow depths sufficient to subdue the weeds but not to destroy the surface mulch of stubble and other crop residue.

METHODS OF SEEDING

Preliminary results obtained at Hays, Kans., and Woodward, Okla., indicate that grasses may be seeded without nurse crops more successfully than with nurse crops of oats, barley, Sudan grass, or rye. Alfalfa and sweetclover, except when sown under especially favorable conditions, resulted in consistently poorer stands when seeded with companion crops of oats and barley than when seeded alone. Similar results were obtained in limited trials with grasses. Four strips of thickly and thinly seeded oats were made across 70 strains of grass seeded alone and with mixtures of three other grasses at Woodward in the spring of 1937. The season after seeding was extremely dry until late in the summer. The oats made rapid early growth but produced very little forage. In every instance the stands of grass were consistently poorer among the oats than on adjacent weed-infested areas, especially where the weeds were thin.

Results of similar significance were obtained where blue grama was broadcast alone and with Sudan grass planted in rows spaced

4, 12, 24, 36, and 48 inches apart. In every comparison, despite weed competition, the stand and vigor of blue grama seeded alone were better than among the growing Sudan grass. Practically none of the grama plants survived in the 4-, 12-, and 24-inch spacings of Sudan grass, but the stand and vigor between the 48-inch rows were nearly equal to areas seeded alone. This indicates the possibility of establishing grass by seeding in wide-spaced rows of growing Sudan grass for winter protection.

Comparable results were obtained at Woodward, Okla., during the favorable growing season of 1938 when five native grasses and one introduced species were seeded alone and with Sudan grass and milo spaced 18, 36, and 72 inches apart. The stand and vigor of the pasture grasses seeded alone were much superior to those sown with nurse crops and were better among the wide-spaced nurse crops than among the closer spacings.

In 1936, results obtained by B. F. Barnes, Superintendent, United States Dry Land Field Station at Dalhart, Tex., indicate that almost any kind of growth that provided shade and reduced soil temperatures was beneficial to the survival of blue grama seedlings. These results indicate further that thinly seeded nurse crops may be helpful under certain conditions.

Successful stands of many grasses have been obtained by broadcasting, but where feasible, drilling has proved to be more satisfactory and less wasteful of seed. A combination of drilling and broadcasting appears to have preference over either method used alone. Drilling usually places all the seeds in contact with moisture, which is desirable because it causes the seeds to sprout; but unless additional moisture is received the seedlings may die. This hazard may be reduced by using a drill with one-half of the spouts removed from the disks to broadcast some seed while the other half of the drill is placing seed in contact with moist soil just below the surface. This provides at least two opportunities for a stand. The broadcast seed may take advantage of moisture falling too late to save the drilled seedlings from drought damage.

A drill suitable for this purpose and capable of sowing all kinds of grass seed has been assembled at Woodward from ideas originally used there by James E. Smith, regional nurseryman, Soil Conservation Service, United States Department of Agriculture, Amarillo, Tex., and B. F. Barnes. They successfully used a cotton planter to seed blue grama in rows. Later a similar machine with suitable plates for cotton, corn, milo, kafir, and sorgho was used satisfactorily at Woodward in planting 33 species of pasture grass in rows. Recognizing the need for a close drill capable of performing the same functions as the planter, the necessary parts were obtained by E. F. Chilcott, Superintendent, United States Southern Great Plains Field Station, and assembled at Woodward in the spring of 1937 by J. J. Brenner and C. L. Sheley, of the Division of Dry Land Agriculture, under the direction of Chilcott. The result was a six-row, 14-inch drill which has proved satisfactory in obtaining initial stands of many grasses, including the bluestems, silver beardgrass, and Indian grass, all of which are usually more difficult to drill than blue grama. This drill has been further improved by adding six more planter

boxes, making a 7-inch drill with alternate chutes for drilling and broadcasting simultaneously (fig. 2).

By placing a suitable agitator in a common grain drill, the Soil Conservation Service at Dalhart, Tex., developed a satisfactory method of drilling blue grama. In 1935 a satisfactory stand of blue grama was obtained at Hays, Kans., by forcing the light seeds through a common grain drill with a mixture of sand which caused some wear on the drill mechanism. This stand was still surviving early in 1938.

Planting grasses in rows may be satisfactory for such species as bluestem (western wheatgrass) which spreads rapidly by vegetative means. J. F. Brandon, Superintendent, United States Dry Land Field Station, Akron, Colo., successfully established this grass by transplanting it on fallow land in the spring, in rows spaced 3 feet apart, and



FIGURE 2.—A planter-type grass drill designed and constructed at Woodward, Okla., showing seed being broadcast from the front row of boxes and drilled shallow from the rear. Note the protective crop residue on this seedbed of disked Sudan grass stubble.

cultivating most of the first season to control soil blowing, subdue weeds, and enable the plants to become well established. Cultivation was suspended near the end of the first season and the vigorous root-stalks had spread to cover the intervening spaces by the end of two more seasons. Clean-tilled land blows so readily that clean tilling is considered a poor method of preparation unless the plantings are made as indicated above and cultivated to control blowing, or seeded in the fall and protected by lister furrows or rows of Sudan grass. Western wheatgrass may be planted in rows on Sudan grass stubble land. This reduces the cost of seed and is fairly successful if the seed is placed in contact with moisture. Cultivation should not be necessary to control soil blowing on dense stubble land and may be dispensed with if the land is reasonably clean and free from weeds.

DEPTH OF SEEDING

Practically all grasses require shallow seeding, the actual depth depending on size of seed and texture of soil. Satisfactory emergence with most perennial pasture grasses has been obtained from seedings made at depths ranging from $\frac{1}{4}$ to $1\frac{1}{2}$ inches. Slightly deeper plantings have been satisfactory on sandy soils. Preliminary results indicate that the optimum depth for average conditions is about one inch. Distributing the seed uniformly throughout the range of depths mentioned above will prolong the period of emergence but insure against total failure, if subsequent conditions prove to be especially adverse for any one depth.

RATE OF SEEDING

Optimum rates of seeding vary with such a wide variety of conditions that few reliable suggestions can be offered until more extensive trials are completed. Some of the factors that influence the rate of seeding are size and quality of the seed, i. e., the number of viable seeds per pound; purity or freedom from foreign or inert matter; method of seeding; and, if in rows, the distance between rows; preparation of seedbed; spreading habit of the grass; and climatic conditions. Broadcast seedings require heavier rates than close-drilled seedings. A few grasses, including sand dropseed, sand paspalum, buffalo grass, and Indian ricegrass, respond to seed treatment in the form of freezing, aging, or scarification. The price of seed often determines the amount to use. Grasses capable of spreading rapidly by vegetative means or by natural reseeding may be sown at thinner rates than those that spread more slowly.

The number of seeds per pound has been computed for many grasses, and, this information if used in connection with tests of purity and germination, will be helpful in determining suitable seeding rates for special conditions.

DATE OF SEEDING

With few exceptions most grasses adapted to the central and southern Great Plains may be sown to best advantage medium early in the spring after there is no further danger of frost. High winds are often less prevalent at this time than earlier in the spring; temperatures are more favorable to rapid growth, and precipitation is usually higher and better distributed. A study of weather records by Chilcott (10), indicate that these favorable conditions are more apt to prevail after the middle of April than before that time. When surface moisture is available in abundance and wind-resisting stubble is present early in the spring, the grass may be seeded in the undisturbed stubble as soon as the weather moderates and before weeds have started growth. This eliminates the necessity of partly destroying the stubble by surface tillage in advance of seeding and gives the grass an even start with the weeds. Soil moisture, however, is seldom sufficient to risk seeding early in the spring. Light precipitation at this time often starts many weeds but fails to provide sufficient moisture to maintain the slow-growing grasses through periods of high winds until more rains are received. When early moisture is inadequate, seedings should be delayed until more

rain falls and weeds are destroyed by tillage. Seedlings unduly delayed in the spring are often damaged by torrential rains and rapid drying of the surface soil. Seeding when the ground is dry, "dusting in," has been successful in a few instances, but the chances of total failure are too great to recommend this method.

Canada wild-rye, bluestem (western wheatgrass), and Texas bluegrass respond to cool weather, and therefore usually thrive best when sown early in the spring or in the fall (fig. 3). Many other grasses



FIGURE 3.—Grasses sown in the fall of 1937 at Woodward, Okla.: *a*, Crested wheatgrass; *b*, bluestem (western wheatgrass); *c*, Canada wild-rye; *d*, Virginia wild-rye; *e*, blue grama. The last has an excellent stand, but the plants were too small to show well in the illustration.

less resistant to cold may be sown advantageously in the fall when conditions are especially favorable. Seedlings made early enough in the fall to survive the winter in good condition usually contain very few weeds the following spring, whereas spring seedlings generally become infested with weeds no matter how carefully the land is prepared in advance. Fall seeding should likely be protected from blowing by planting a row of Sudan grass every 48 inches, unless the seedbed already contains sufficient wind-resisting stubble.

Although medium-early spring planting appears to be best for most grasses adapted to the region, preliminary results obtained at Woodward indicate that fall seedings may be successful under certain conditions. Most of the 33 species sown on September 12, 1936, emerged satisfactorily and 16 survived the winter. Fair to excellent stands were likewise obtained in 1937 from 32 out of 34 species and strains sown on September 5, 13 out of 14 sown on September 6.

and 6 out of 10 sown on September 17 and again on September 18. Several satisfactory initial stands of crested wheatgrass and smooth brome (bromegrass) were obtained from fall seedings made in different years at Hays, Kans.

BROADCASTING MATURED HAY

Until native grass seeds become cheaper and more generally available, many farmers and ranchers will benefit by mowing mature stands of native grass mixtures on meadows, roadsides, and deferred pastures. This material may be cured in small ricks and the following spring scattered unthreshed over thin pastures or cultivated areas reserved for reseeding. Successful stands have been obtained by this economical procedure, which may be adopted advantageously throughout the region.

TREATMENT AFTER SEEDING

COVERING THE SEED

Broadcast seedings may be covered by crisscrossing the land with an empty drill set at shallow depths. A disk harrow, with the disks set straight, may be used where the surface soil is firm enough to avoid covering the seeds too deep. Packing the land with a close-set surface packer is advisable where sufficient crop residue is present to prevent soil blowing. A herd of sheep or cattle may be used advantageously to cover broadcast seedings, especially on rough range land infested with brush.

EXCLUDE LIVESTOCK FROM NEWLY SEEDED AREAS

All livestock should be excluded from areas reseeded with grass during the entire growing season of the first year and during the early part of the second growing season. This provides an opportunity for the young plants to become established, and enables additional plants to emerge later in the year or the following spring. Grazing, if practiced at all on spring-sown grasses, should be moderate and delayed until the latter part of the growing season. Complete recovery on reseeded areas would be hastened by confining the grazing to the winter season. Hanson (31) in 1928 suggested that areas undergoing revegetation should be protected from grazing at least 1 year, and that maximum forage yields and highest carrying capacities could be secured on these areas after the first year by using the deferred rotation system of grazing.

CLIPPING WEEDS

Weeds may be controlled more effectively and with less harm to the young grasses by clipping with a mowing machine than by the use of livestock. The mower should be equipped with raised shoe bars so as to leave a stubble about 8 inches high. Closer clipping is preferred for buffalo grass.

ADAPTED GRASSES

Many native and introduced grasses and browse plants are now undergoing thorough trial at a few stations in the region. A total of 521 species, many additional strains, and 75,775 isolated plants are

under observation at the Southern Great Plains Field Station, Woodward, Okla. Among these are several already known to be well adapted to Plains conditions and which show promise of lending themselves to domestication. Preliminary breeding work indicates that vast improvements can be effected by rigid selection among the highly variable plant types representative of nearly every species.

One of the first reports of range-improvement studies in the West was issued in 1895 (64). Although this early work was discontinued before much was accomplished, the report indicates what may be expected from further studies of native species.

The importance of improving the native grasses for cultivation was noted by Pammel (49) from range studies conducted in 1896 in central and northern Colorado. He states (49, pp. 15-16):

If by selection from the native grasses an improved form of Western Wheatgrass or Grama grass can be introduced into the "semi-arid" region which will give greater returns than those already there, the live-stock industry will be put on a better basis and its success assured.



FIGURE 4.—Results of 2 days' collection of native grass seeds near Chico, Colo., in the last century; reproduced from Shear (62).

About the time of these studies seeds of native grasses were collected in large quantities and tested extensively in the West. A large supply of seed collected during a 2-day period near Chico, Colo., was reported by Shear (62) in 1901 (fig. 4). Nelson (46) reported wonderful results (in 1897) from seeding the ground to some of these, especially the wheatgrasses. Buffum (8) collected seed as early as 1891 and later concluded that native grasses would certainly yield to cultivation. In 1893 he reported that seeds of western wheatgrass, grama, and switchgrass already had a market value.

BLUE GRAMA

Blue grama, despite its extreme tardiness in naturally reclaiming abandoned fields, probably ranks first among well-adapted native species for reseeding cultivated land in the drier parts of the southern Plains. Its possibilities for revegetation purposes were noted by investigators nearly 40 years ago. Lamson-Scribner (42) reported that in 1898 blue grama seemed to be one of the two most promising grasses grown in the testing gardens. He stated (42, p. 147):

The seed of blue grama is easily harvested, and so far as our experiments go, it grows readily from seed. We believe that the propagation of this grass upon the cattle ranges of the West would greatly improve their value for grazing.

He (43) stated in 1899 that blue grama was readily propagated by seed and grows in most any kind of soil.

Aldous (2) stated that blue grama was one of the most promising grasses to use in revegetating land in western Kansas, and Wilson (74) in 1931 reported that blue grama appeared to be one of the most valuable species for artificial reseeding of range land. The latter reported an average germination of 40.3 percent for seed collected over a 7-year period. In 1930 he used a bluegrass stripper in harvesting blue grama seed.

In recent years the Soil Conservation Service has adopted and improved the stripper method of harvesting blue grama. James E. Smith has clearly demonstrated that viable seed of this species may be gathered satisfactorily in large quantities. This seed was limited to use on demonstration projects, so none was available to the general public until 1937 when farmers began collecting it on a commercial scale. Methods of harvesting the seed and suggestions for its use in erosion control are discussed by Fults (23).

It is now considered economically feasible for a farmer or rancher to purchase quantities sufficient to attempt extensive seedings. Five to ten pounds per acre may be expected to furnish satisfactory stands under favorable conditions, since each pound contains about 1 million seeds. The use of less seed would reduce the cost, occasionally provide a satisfactory stand, and usually furnish a few plants for natural reseeding. Since this species tends to reseed itself very slowly under natural grazing conditions, reasonably heavy seeding is assurance against initial-stand failure and delayed final coverage.

In 1937 four rates-of-seeding tests of blue grama, each test including 8 to 10 rates ranging from 1 to more than 20 pounds per acre, were conducted at Woodward. Separate tests were made in variously spaced rows of growing Sudan grass, on rowed kafir stubble with and without a mulch of wheat straw, on sagebrush-infested pastures (receiving different treatments for shrub control), and on rye stubble. The first two seedings were made on April 28 and the last two on May 18 and 22, respectively. Conditions were favorable for prompt emergence on the first date of seeding, but were much less favorable for emergence on the other two, although fair to excellent seedling stands were obtained in most instances from the thicker rates. A severe drought prevailed from shortly after seeding until late in the summer, the growing season (April to September) being the driest

since 1914. Grasshoppers were extremely numerous and damaging to all stands, despite repeated efforts to control them. Under these conditions, which could hardly be more adverse, the higher rates of seeding, 20 pounds or more, gave the most satisfactory final stands. None approached satisfaction until the rates exceeded 12 pounds. Similar results were obtained in 1938. Since these are the results of but 2 years, they are not conclusive, but they suggest caution against extremely low rates of seeding.

Although initial stand failures have resulted from many seedings of blue grama attempted during drought years, other seedings made under more favorable conditions at seeding time were so successful that the stands were often too thick to survive subsequent drought. In 1935 a thick seeding, estimated at more than 20 pounds per acre, produced an excellent vigorous stand at Woodward (fig. 5). After



FIGURE 5.—Blue grama sown at Woodward, Okla., in 1935, as it appeared in 1936, showing clean stand compared with weedy plots of other grasses in the background.

becoming apparently well established and producing seed the first year, many of the plants died during the drought of 1936, and practically all of the remainder died in 1937. It is probable that this stand was too thick to become properly rooted before additional drought ensued. Similar results were obtained from seedings irrigated only at seeding time in the fall of 1936, when blue grama was seeded thickly on September 12. An extremely thick stand resulted and survived the winter in excellent condition. Most of the plants died during the drought of 1937. In the same seeding galleta grass survived with much less injury.

The 7 main survivors of the 70 species and strains seeded on April 21, 1937, are listed in descending order of drought survival of first-year growth: Galleta grass, hairy grama, buffalo grass, blue grama, plains bristlegrass, sand dropseed, and rough rush grass. Very little

difference was noted in the drought survival of hairy grama, blue grama, buffalo grass, and plains bristleggrass, although more of the blue grama seedlings died than did those of buffalo grass. Others which survived to a limited extent included side-oats grama, weeping lovegrass (an introduction from South Africa), jaragua grass (an introduction from South America), bluestem (western wheatgrass), and vine-mesquite. A lack of uniformity in original stands made it impossible to determine exactly the relative drought resistance, but most of the survivors appear to be worthy of further trial. Many other species persisted for different periods of time before yielding to heat and drought, and several died just before the fall rains began. Several others might have survived had they been established for longer periods before the drought started. Included among the grasses which failed to survive the summer were crested wheatgrass and bromegrass.

Regional grass surveys conducted in 1935 (58) indicated that blue grama is adapted to a much wider range of climate, soil texture, and altitude than buffalo grass and was an important species on practically all soil textures studied. It proved to be less resistant to clipping and heavy grazing than buffalo grass but was superior to most others in these respects. Observations indicate that blue grama survives a deeper covering of wind-deposited silt than the somewhat shorter growing buffalo grass.

Rydborg and Shear (52, p. 14) reported in 1897:

It [blue grama] is one of the best pasture grasses of the arid plains and bench lands of the West, and far excels, in general opinion, the true Buffalo-grass (*Bulbilis dactyloides* (Nutt.) Rafin), which has gained much of its credit at the expense of Bouteloua, the two being often confused by farmers and ranchmen. Under favorable circumstances it produces a much larger crop than is usually supposed.

Hundreds of individual plants of blue grama selected and isolated at Hays, Kans., and Woodward, Okla., exhibit striking differences in growth characters. The outstanding strains are now being selfed in an effort to fix the desired characters preparatory to further improvement by hybridization and reselection.

BUFFALO GRASS

Buffalo grass repossesses abandoned fields much more rapidly and more completely than blue grama, and abandoned fields fully covered with buffalo grass have withstood the drought much better than adjacent virgin pastures. Practical methods of harvesting the seed in commercial quantities have not been perfected, and many years may be required to develop seed-producing strains suitable for harvesting easily. In view of these facts, wider efforts should be made to reestablish the grass by vegetative methods. By spacing the sods at wide intervals, sufficient to provide a nucleus of this rapid spreading species, the cost, which is mainly for labor, can be greatly minimized, and the process of revegetation materially hastened. Sod in good condition for this purpose is scarce in the region at the present time but usually may be found in considerable abundance in the vicinity of buffalo wallows, on old abandoned fields, and perhaps later on, in contour furrows. Two farmers near Quinter and Hays, Kans., suc-

cessfully resodded large fields with buffalo grass by dropping pieces of the sod at intervals of 10 feet in furrows spaced 10 to 12 feet apart (fig. 6). They conducted their work during favorable seasons and reported more rapid spread than was obtained on the average in experiments at Hays. Their resodded fields, when examined in 1936, supported a dense, vigorous stand of buffalo grass, while adjacent pastures were in much poorer condition and showed more evidence of drought injury.

Resodding of buffalo grass may be combined to excellent advantage with reseedling of blue grama and other adapted grasses (57).



FIGURE 6.—A pure stand of buffalo grass in 1936 on a 20-acre field near Quinter, Kans., resodded by J. R. Mohler in 1915 by spacing sods at intervals of 10 feet in furrows spaced 10 to 12 feet apart, showing faint line of one of the original furrows. Mohler reported complete coverage at the end of 3 to 4 years.

The sods of buffalo grass may be scattered on the surface of deeply cultivated land and pressed into the soil with a heavily weighted packer (fig. 7). Where soil blowing is severe, they may be placed in or between contour furrows. The other grasses may be seeded on the packed surface of the resodded land or in strips on Sudan grass stubble between the sodded furrows.

Jared G. Smith was quoted by Shear (62, p. 25) in 1895 as reporting that—

Unfortunately this grass can not be readily propagated from seed on account of its scarcity and the difficulty of collecting it. It can, however, be easily grown from roots and cuttings. The turf may be broken into fragments and planted in shallow furrows, in the same manner that Bermuda grass is planted in the South.

Lyon and Hitchcock (44) in 1904 reported that buffalo grass could be propagated satisfactorily by cutting the sods into small pieces and pressing them into prepared soil. It was stated that if these pieces were spaced 2 feet apart each way they would "thicken up fairly fast in one season."

Fred O. Case and H. E. Mather, of the Soil Conservation Service, recently attempted resodding work on a large scale at Springfield, Colo. During extremely dry seasons they found that the sods survived surprisingly well when all seedings of other grasses failed completely. Similar results were obtained often at Hays, Kans. Sods spaced 3 feet apart in the fall of 1934 survived in excellent condition when failure resulted from all grasses seeded at the same time. At the end of 2 exceedingly dry years recovery on this resodded area was greater than that accomplished by natural agencies on neighboring fields abandoned for 40 years and nearly equal to natural recovery



FIGURE 7.—Resodding buffalo grass at Woodward, Okla., by dropping the sods in furrows made with a spring-tooth harrow and pressing them into the soil with a surface packer, leaving a seedbed suitable for drilling other grasses when refurrowed at intervals to control soil blowing.

at the end of 46 years. The many fine roots produced by this grass are indicative of its aggressiveness and value as a soil binder (fig. 8).

Buffalo grass is adapted only to the heavier types of soil in the region. On June 11 and 12, 1937, sods were set out on Pratt fine sandy loam and Pratt loamy fine sand at Woodward, Okla. Desiccating winds of high velocity occurred at transplanting time and continued intermittently with excessive drought until late in August. Practically all sods set out on the lighter soil failed to survive the summer, but a large percentage on the heavier type renewed growth in the fall. Neither of these soils is heavy enough for best results with buffalo grass.

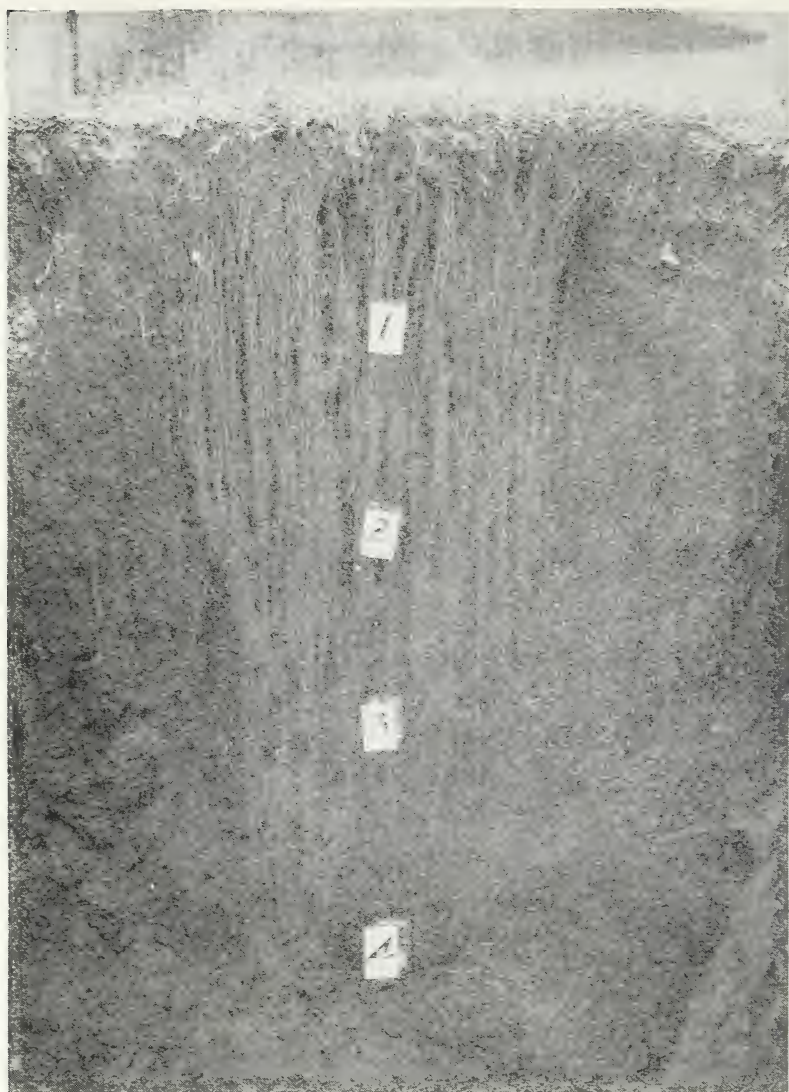


FIGURE 8.—Root system of buffalo grass before the drought, showing depth in feet.

Buffalo grass also has distinct advantages for lawns, golf courses, and athletic fields in the dry Plains (56) (fig. 9).

Several thousand individual plants of buffalo grass have been isolated and studied at Woodward and other stations in the Plains. This material displays highly significant differences in density, vigor, production, spread, seeding habits, resistance to nematodes, and ability of the foliage to remain green late in the season; all of which indicate the possibilities for improvement by intensive selection and hybridization.

This species is ordinarily dioecious, producing the pistillate or seed-producing flowers on one plant and the staminate or pollen-bearing flowers on another. A small percentage of the plants produce both seed and pollen but on different stems arising from the same node, and continue to produce these beyond the second year. Both the dioecious and monoecious plants usually produce seed on extremely short stems hidden among the leaves, while the pollen-bearing spikes are borne on much taller stems extending beyond the leaves. In 1937 a pistillate selection was made at Woodward, having the shape and tall stem of the staminate inflorescence. This chance variation indicates that this species descended from ancestors having perfect flowers (the staminate (male) and pistillate (female) organs in the same flower), and further indicates the possibility of developing still taller seed-producing strains easier to harvest than ordinary plants. Gernert (25) describes other characteristics of buffalo grass and reports upon its differential susceptibility to nematode infestations.

GALLETA GRASS

Galleta grass and black grama appeared to be the most drought-resistant species in preliminary trials at Woodward, Okla. Satisfactory seedling stands were obtained with a large number of grasses seeded on clean tilled land under favorable conditions in the spring of 1936. A torrential rain followed by high winds destroyed most of the plants before they became established, and solid tillage was required to control soil blowing. A few scattering plants of galleta grass survived these conditions and still persisted among grasses transplanted on the area the following spring.



FIGURE 9.—A football field solidly resodded with buffalo grass in the spring of 1936, as it appeared ready for use that fall, at Hays, Kans.

Galleta grass occurs in the western parts of the central and southern Plains but has not yet invaded the eastern portions, which indicates that its usefulness may be limited to the western sections, although it should respond satisfactorily to more favorable conditions prevailing in the eastern Plains. Wooton and Standley (76) refer to this species as probably the second most valuable range grass in New Mexico. Its method of spreading by aggressive rootstocks contributes to its grazing endurance and value as a soil binder. James E. Smith reports having observed this grass growing on a wide range of soil types. It is described by the Forest Service (68) as being highly regarded for summer use but of less value in the winter-cured stage.

Seed of galleta is not available commercially, but has been harvested by stripping in considerable quantity by the Soil Conservation Service. The chaffy seeds have been weaker in germination, fewer per pound, and require thicker seeding rates than blue grama (fig. 10).

In 1937 an attempt was made at Woodward to cross galleta grass with curly mesquite with the object of combining in the progeny the fine quality and vigorous stoloniferous habit of the latter with the superior cold resistance, greater drought endurance, and heavier production of the former. A total of

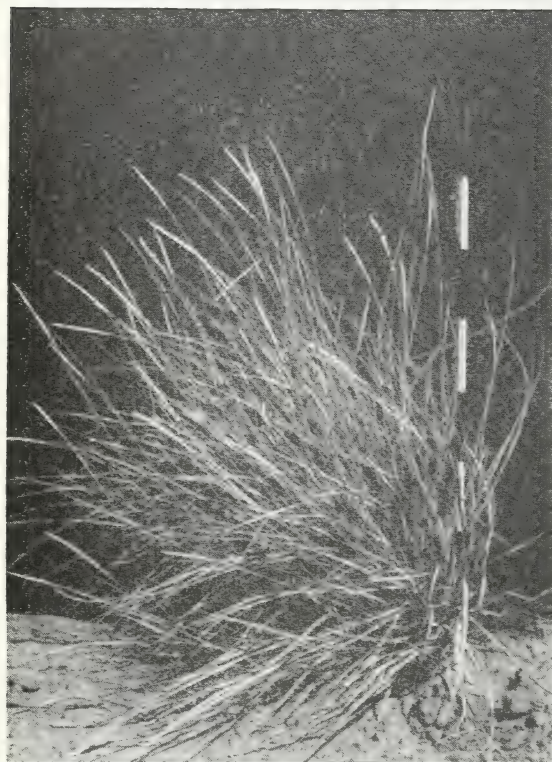


FIGURE 10.—A typical plant of galleta grass in the selection nursery at Woodward, Okla. The bi-colored sections on rule are 3 inches long.

140 florets were included in the attempted cross. It is too soon to evaluate the results of this attempt at improvement.

PLAINS BRISTLEGRASS

Plains bristlegrass, or perennial foxtail, appears in limited trials to be promising. It survived prolonged heat and drought about as well as any strain tested at Woodward in 1937. The growth was vigorous, green, and abundant all season, and many stems and seed spikes were produced. The seeds started maturing early in August and continued to ripen until frost. They matured nonuniformly

throughout the spike and shattered badly before they were fully mature. These defective habits may be responsible for its failure to occupy large areas in the Plains. It occurs sparingly over an extensive region, particularly in parts of eastern New Mexico.

Bentley (*5*) in 1898 reported that this species, which he referred to as "Arizona Millet," was a valuable hay grass because of its habit of growth, producing an abundance of fodder and seed. He further stated that it was one of the most common grasses of the Abilene section of Texas. One strain of this species in 1937 produced more forage but less seed than another at Woodward (fig. 11). Breeding work with these and additional strains may result in improved seeding characters.



FIGURE 11.—Plains bristlegrass: A, Large strain left; small strain right; B, close-ups of large strain; and C, close-ups of small, less shattering strain. The bicolor sections on rule are 3 inches long.

HAIRY GRAMA

Hairy grama occurs sparingly on rocky, caliche, and sandy soils throughout the region. Unlike blue grama it seldom occurs thick enough in natural stands to justify harvesting for seed; consequently, seed supplies must be increased by artificial means. Its palatability is considered equal to blue grama, but the forage production is usually less. Its range of greatest usefulness is limited to sandy soils and to other sites less favorable for the maximum development of blue grama. Several vigorous strains of this species, isolated at Woodward, have produced growth comparable to the better strains of blue grama (fig. 12). Griffiths and his coworkers (30, p. 13) reports as



FIGURE 12.—A selection of hairy grama, showing growth comparable with that of blue grama (fig. 19). The bicolored sections on rule are 3 inches long.

follows concerning this grass, which he calls "rough grama":

The habits of the species render it of much less value than its close relative, the blue grama, but on account of its very wide distribution and abundance as a filler over large areas it is a very important species. It is not a well-rooted species, and consequently does not withstand trampling by stock very well.

BLUESTEM (WESTERN WHEATGRASS)

Bluestem or western wheatgrass is one of the first perennial species to reoccupy abandoned fields in the northern Plains and as far south

as the central latitude of eastern Colorado and western Kansas. This grass decreases in importance as this line is approached from the north and is superseded by sand dropseed and red three-awn in natural revegetation farther south. Western wheatgrass occurs sparingly throughout the southern Plains, but since the recent period of prolonged drought and excessive grazing it is confined mainly to the lower lands and lightly grazed areas. Kennedy (38) reported in 1900 that western wheatgrass grew luxuriantly all over central Texas and withstood the droughts to which that section of the country was periodically subjected.

In the southern Plains it is considered less palatable and not nearly so resistant to drought and grazing as the short grasses, but is more productive under favorable conditions and is considered fairly nutritious at all stages of growth. This species is capable of spreading rapidly by vigorous creeping rootstocks, which adds to its value as a soil binder, assists in overcoming its susceptibility to close grazing, and reduces the seeding rate required to obtain an excellent final stand (fig. 13). Fairly viable seed has been harvested satisfactorily



FIGURE 13.—Bluestem (western wheatgrass) planted in rows in the fall of 1936 at Woodward, Okla., as it appeared early in 1938, showing vigorous spreading habit.

with a combine, and limited amounts have been on the market for several years. Cleaned seed passes readily through a common grain drill and germinates promptly. The young plants often succumb to hot weather and drought before they become well established, which emphasizes the desirability of seeding early in the spring or fall. Newly harvested seed often germinates less than seed that has undergone several weeks of after-ripening. Successive weekly germination tests at Woodward in 1938 revealed that the seed gradually increased in viability from a trace at harvesttime in August to 50 percent on October 1.

For best results sources of locally adapted seed of this species should be established for use in the southern Plains. Preliminary results indicate that northern strains produce less forage, spread slower, and are less capable of withstanding intense heat, combined with drought in southern districts. The grass prefers heavy soil but has been observed in considerable quantities on sand near Akron, Colo., North Platte, Nebr., and Woodward, Okla.

BLACK GRAMA

Black or woolly-foot grama occurs in the western parts of the southern Great Plains and is one of the principal pasture grasses of the southwestern semidesert region where it is favorably regarded for drought resistance, palatability, and general grazing value throughout the year. It is more resistant to drought than blue grama and spreads both by seed and surface runners or decumbent stems, but is less palatable and the seeds are usually much weaker in germination. Preliminary trials indicate that this species may have a place in revegetation work in the drier parts of the Plains. Cassady (9) suggests transplanting this grass to thicken stands on depleted ranges in the Southwest. The Forest Service and the New Mexico Agricultural Experiment Station have intensively studied the range value of this grass on the Jornada Experimental Range in southern New Mexico, as reported by Nelson (47). The chemical composition of this and other range plants of New Mexico was reported by Watkins (69), who found that black grama is comparatively high in vitamin A, and only slightly less palatable than blue grama or buffalo grass.

SIDE-OATS GRAMA

Side-oats or tall grama is highly palatable and nutritious, especially during the growing season, but it is less valuable in these respects than blue grama and is not rated so highly in the winter-cured condition. It usually produces more and earlier forage than blue grama, but is less resistant to drought and grazing, and requires more moisture for maximum development. Side-oats grama spreads slowly by short rhizomes, is an important constituent of pastures and hay meadows on sandy soils, and is worthy of consideration in grass mixtures. The stems are rather tall and produce an abundance of seed which is harvested with ordinary farm machinery but is comparatively low in germination (fig. 14). The Forest Service (68) states that because of its size, vigorous growth, adaptability to varying growth conditions, and economic value, it appears to be the most promising grama for domestication.

Bentley (5, *p. 12*) in 1898 reported that side-oats grama was one of the best native grasses in central Texas and was highly regarded by stockmen. He further stated:

Cattle are very fond of it both before and after it ripens seed. It produces a great many seeds that do not shatter out readily, and, as it grows from 18 inches to 3 feet tall and makes a large quantity of fodder, soft when cured, it is an excellent hay grass. It is common throughout the prairie region * * *.

In 1899 Bentley (6) transplanted sods of side-oats grama and several other grasses, including curly-mesquite, in bare spots in native pastures and reported that in every instance they grew well and promised to cover the naked spots in a short time.

SAND DROPSEED

Sand dropseed is one of the first perennial grasses to invade abandoned fields, waste places, and disturbed areas in native pastures of the southern Plains. Consequently, with most pastures badly damaged by drought and grazing, this species is now widely and rather abundantly distributed. Many years are required for the better

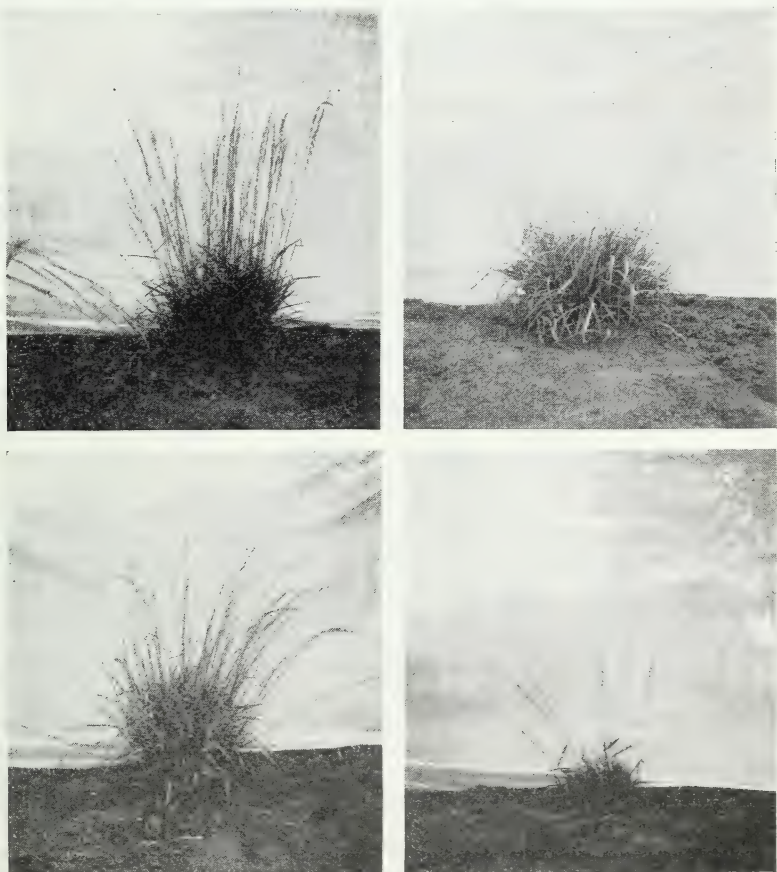


FIGURE 14.—Selections of side-oats grama at Woodward, Okla., showing typical variation in this species.

grasses to make much progress in replacing it on abandoned land, and it is seldom crowded out entirely in pastures. Sand dropseed serves as a prompt and effective stabilizer for denuded areas where it provides a preparatory cover for slower reoccupancy by more desirable species. It is considered of less value for grazing than the short grasses but often produces more forage, especially during hot weather. It grows on a wide range of soil types but thrives best on sand. Recovery of range areas from the effects of drought and other adverse conditions will not be complete until sand dropseed is more fully replaced by other more desirable species.

This grass usually produces an abundance of very small seeds, averaging about 5 million per pound and is adapted to seeding with an alfalfa drill or with the new planter-type grass drill equipped with very small plate holes. The hard seeds respond to freezing temperatures, aging, and scarification. Natural succession may be simulated by seeding sand dropseed in pure stands, and following a year or more later with blue grama or other species. It is believed best, however, where dropseed is used, to seed it at the same time the other grasses are sown. Where seeds of the better grasses, such as blue grama, are available, it is believed best to seed them in the stabilizing cover of noncompetitive Sudan grass stubble, rather than in competition with growing plants of sand dropseed.

SAND GRASSES

In addition to sand dropseed, side-oats, and hairy grama, the principal perennial sand grasses are turkeyfoot (sand bluestem), prairie beardgrass (little bluestem), sand lovegrass, Texas bluegrass, Canada wild-rye, sand paspalum, switchgrass, Indian grass, giant reedgrass, blowout grass, and vine-mesquite.

The importance of these grasses is indicated by the necessity of revegetating many sandy areas in the region. Chilcott (11) reported that in the drier and sandier portions of the country much regrassing was essential to control soil drifting and to make the best use of land. He pointed out that the great value of a permanent crop, such as grass, was to tie down part of the soil and to prevent movement of the remainder from one field to another.

TURKEYFOOT (SAND BLUESTEM)

Turkeyfoot or sand bluestem is a very tall, vigorous, fairly palatable sand grass, spreading by strong rootstocks. It is one of the grasses legendarily described as growing "stirrup-top" high in the early days. Plants of this species, selected at several locations in the Plains, exhibit every conceivable variation in color, quantity, and quality of growth. This species has been referred to as a sand expression of bluejoint turkeyfoot (big bluestem), which is primarily adapted to heavy soils receiving more precipitation than commonly occurs in the dry Plains. Lamson-Scribner (41) stated, in 1896, that the agricultural value of sand bluestem was probably about the same as that of big bluestem, and that it seeded freely and the seeds were easy to collect.

PRAIRIE BEARDGRASS (LITTLE BLUESTEM)

Prairie beardgrass or little bluestem, a medium-tall, vigorous-growing bunch grass, is well adapted to both sandy and heavy soils, but

is more susceptible to drought than most other grasses in the dry Plains, many plants being killed or damaged badly in recent years. This species is highly regarded as a palatable and fattening summer forage in the famous Flint Hills district of eastern Kansas and the Osage section of eastern Oklahoma, but is considered much less palatable in comparison with other species in the western parts of these States. It is a mediocre winter forage in the cured stage but reclaims abandoned land more rapidly than turkeyfoot. The light fuzzy seeds are produced on tall stems and are easily harvested, but they shatter readily, are low in germination, and difficult to drill without special mechanism.

SAND LOVEGRASS

The value of sand lovegrass has rarely been appreciated or mentioned by investigators, and it has not been considered of sufficient importance to be assigned a common name, although it is referred to here as sand lovegrass. Most lovegrasses are of a weedy nature, but this one is so highly relished by livestock that it has been largely eliminated except in the protection of sand sagebrush, skunkbrush, and other pasture shrubs. It is one of the most important species on sage-infested land in northwestern Oklahoma and occurs sparingly on other sandy areas in the region, especially where it has been partly protected from close grazing.

This species is a medium-tall, vigorous, leafy bunch grass, capable of remaining green most of the summer in the face of severe drought. It renews growth fairly early in the spring and retains its luxuriant green condition until late fall, when the leaves and stems turn reddish brown. The tall, suberect stems and spreading panicles are prolific seed producers (fig. 15). The seeds are extremely small, do not shatter readily, thresh clean from the glumes, weigh about 60 pounds to the bushel, and usually have a high percentage of germination. The number of seeds per pound is similar to that of sand dropseed, 1 pound per acre, well distributed, being sufficient to provide a satisfactory stand under reasonably favorable conditions. This grass could be included advantageously as a component of grass mixtures for sandy land.

TEXAS BLUEGRASS

Texas or plains bluegrass is an important grass on sandy pastures in the eastern part of the southern Great Plains. This dioecious species starts growth extremely early in the spring, goes dormant in midsummer, and renews vigorous growth in the fall. It spreads rapidly by underground stems and makes a fairly dense sward where moisture is plentiful or grazing not too severe (fig. 16). Because of its high palatability and active growth when other plants are dormant overgrazing has caused its virtual elimination, except in the protection of sage and other shrubs, where it still retains the nucleus for rapid recovery.

Hitchcock (36) and Silveus (63) describe this grass as having been cultivated for winter pasture. Lamson-Scribner (41) reported in 1896 that this grass had been introduced into cultivation in the Southern States and was highly regarded as a permanent pasture grass. Successful crosses with Kentucky bluegrass are reported by Oliver (48).

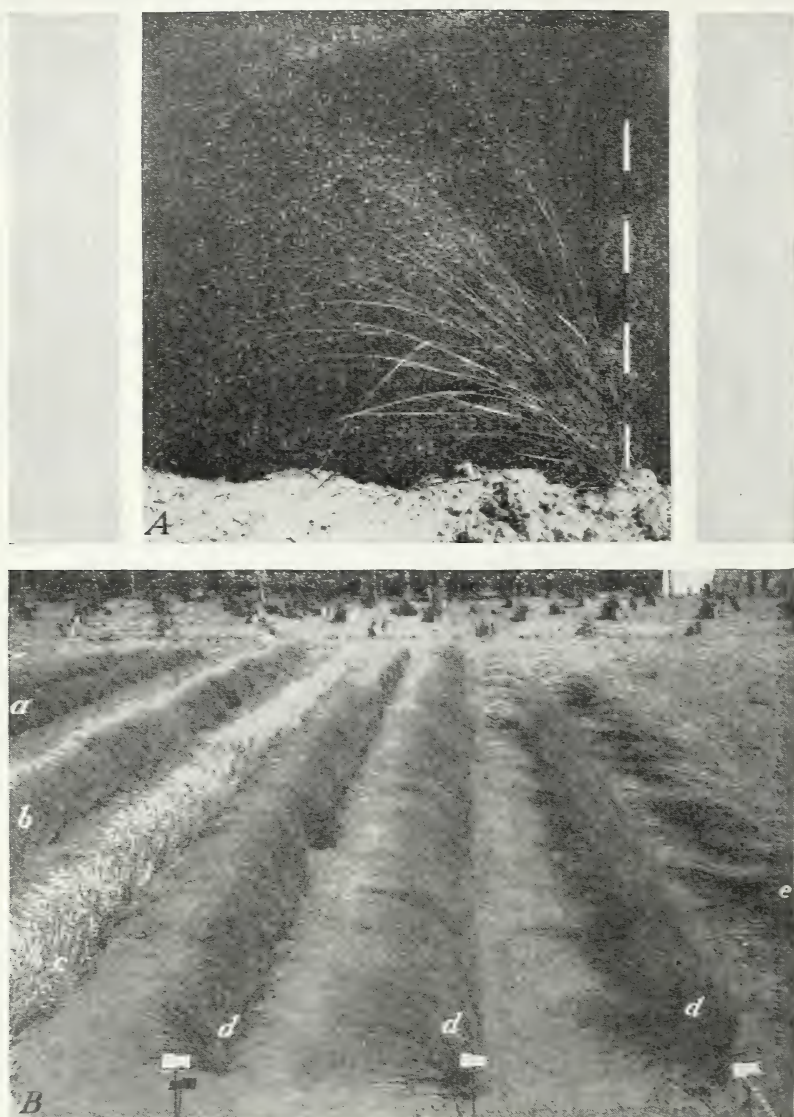


FIGURE 15.—A, Close-up of sand lovegrass, showing spreading panicles and numerous florets. B, Grass nursery at Woodward, Okla.: a, Weeping lovegrass; b, *Eragrostis lehmanniana*; c, *E. secundiflora*; d, strains of sand lovegrass; e, *Sporobolus fimbriatus*.

CANADA WILD-RYE

Canada wild-rye is similar in many respects to blue stem (western wheatgrass), except that it is a tufted species and depends entirely on seeds for propagation and spread. It provides early spring and late fall pasturage. The plants mature early and remain dormant during the summer, the dry stems being of little value for forage at that time. This appears to be an excellent grass to include in mixture with other grasses to make a better balance of pasturage throughout the season, as it provides rich palatable green forage in early spring and late fall.

SAND PASPALUM

Sand paspalum is an exceedingly palatable, soft-leaved bunch grass of wide occurrence on sandy soils, where close grazing has not wholly eliminated it. The plants are most abundant in pastures grazed only in the winter or in the protection of sagebrush on continuously grazed areas. The seeds are produced in fair quantity on rather long stems that spread out fairly close to the ground making them somewhat difficult to harvest, especially since the seeds shatter readily. Removal of the seed hulls by scarification at Woodward has resulted in increased germination.



FIGURE 16.—Two strains of Texas bluegrass at Woodward, Okla.; short form in foreground, tall form in rear.

SWITCHGRASS

Switchgrass is a tall, vigorous, broad-leaved, meadow grass with spreading panicles. It produces a considerable quantity of seed closely resembling millet when threshed. The tall form of this species thrives best on low, fairly moist, sandy bottoms, but the short form is distributed sparingly throughout higher pastures. In the early stages of growth it is palatable to all classes of livestock and makes hay of good quality when cut before the plants are fully

mature. Under favorable conditions it spreads by underground root-stocks, making a fairly dense soil-binding sod. In 1895 Jared G. Smith, as quoted by Shear (62, *p.* 25), reported:

Switch grass produces a very luxuriant growth, especially in the bottom lands and "draws." As it is inclined to get hard and woody when old, it should be cut before it has reached maturity. It is of most value for hay, being rather coarse for pasture. Its seeds are large and abundant and easily harvested. As it has been found to grow well under cultivation, it may be recommended especially for use in mixtures with other grasses.

INDIAN GRASS

Indian grass is a tall, palatable, tufted grass sparingly distributed over sand-hill pastures in the southern Plains, but it seldom occurs in pure stands except on fairly moist bottom land. Cattle relish this grass so much that they have nearly eliminated it, except in the protection of rank-growing shrubs. The large tawny-haired seeds are easily broadcast but difficult to drill, except with special mechanism. The prompt germination and strong seedling vigor of this species are noticeably helpful in establishing stands. This grass continues active growth later in the fall than the bluestems and other closely related species but is equally slow in renewing growth in the spring.

GIANT REEDGRASS AND BLOWOUT GRASS

Giant reedgrass and blowout grass are noted for the prompt and effective manner in which they occupy and stabilize active sand dunes and blowout areas. Although lacking in palatability in comparison with many other species, they serve an important and useful purpose in overcoming the effects of serious wind erosion in sandy localities (fig. 17). After stabilizing an area, they are gradually



FIGURE 17.—Blowout grass naturally stabilizing a sand dune near Waynoka, Okla., showing giant reedgrass, the tall grass in the center background.

replaced with more palatable species. Lamson-Scribner (41) reported in 1896 that *Redfieldia flexuosa* (blowout grass) was valuable for binding sands, and that it was a conspicuous grass and almost the only one found on the sand dunes south of the Arkansas River, near Garden City, Kans.

VINE-MESQUITE

Vine-mesquite, often referred to as panic grass, spreads amazingly fast by extensive surface runners forming luxuriant, rather dense mats on sandy bottoms and moist arroyos in the southern Plains and southwestern semidesert region. Isolated plants of the species have been observed on dry upland soils in the vicinity of Dalhart, Tex., and Woodward, Okla., after prolonged drought, indicating the possibilities of selecting a strain better adapted to dry conditions. Seedling plants of this species were spaced 4 feet apart at Woodward in the spring of 1937 and, despite dry conditions until late August, had covered practically all intervening spaces by fall, some of the stolons being 10 feet in length. This growth character enables the plant to recover from grazing and indicates that this species would be excellent for gully control in sandy localities. Hendricks (35) reports upon the value of this grass for erosion control on southwestern ranges.

OTHER NATIVE GRASSES AND INTRODUCTIONS

A number of other native grasses and several species introduced from Siberia, Australia, India, South America, South Africa, and other countries are under close observation and show some promise of becoming adapted to domestication in the region, although further trial will be necessary before definite conclusions can be drawn. Clements (14) offers a word of caution regarding the use of introduced species by stating that the grasses of a particular climax were the best adapted to its climate and had a distinct advantage in terms of competition over introduced ones.

Quackgrass, F. P. I. 58866, which has been erroneously referred to as *Agropyron pungens*, is a special strain of quackgrass introduced from the Kew Gardens in England and perhaps originally from Siberia. It has been tested at Hays, Kans., since 1927 and shows promise for early spring and late fall growth, forage production, and seeding habits. It spreads in the same manner as the common quackgrass and, consequently, might become difficult to eradicate in humid regions. However, no difficulty was experienced at Hays in ridding the land of this grass by tillage operations ordinarily used in preparing for wheat. The strain has been less drought resistant than the native short grass but has possibilities, particularly for use in gully control and on other favorable locations.

Weeping lovegrass, an introduction from South Africa, shows considerable promise for prompt emergence, strong seedling vigor, rapid vigorous growth, and resistance to heat and drought. Under favorable conditions this perennial bunch grass produces an abundance of very small seed on rather tall erect stems (fig. 18), with a luxuriant basal growth of extremely long, slender, pliant leaves, which appear to be somewhat coarse and fibrous, but, when offered to livestock,

were eaten readily. The seeds are high in viability and under favorable conditions germinate soon after they shatter and fall to the ground. The species reseeds itself readily. Little is known about the winter hardiness of this grass. Most species from South Africa are unable to withstand lowest temperatures at this latitude. Although it winter-killed completely at Colorado Springs, Colo., it survived sparingly during a mild winter at Lincoln, Nebr., and has survived winters at Woodward, Okla., Tucson, Ariz., and Tyler, Tex. Reports from Australia (39) state that this grass is very drought-resistant under semiarid conditions in that country.



FIGURE 18.—Typical plant of weeping lovegrass at Woodward, Okla. The bi-colored sections on rule are 3 inches long.

CRESTED WHEATGRASS AND SMOOTH BROME (BROMEGRASS)

Crested wheatgrass and smooth brome (bromegrass) have proved to be extremely drought-resistant and well adapted to the northern Great Plains (51, 71), but they are unable satisfactorily to withstand high temperatures combined with drought in most of the southern Plains. They are considered fairly promising in the foothills and high moun-

tain valleys of New Mexico⁶ and Colorado, but in the drier parts of the Plains they have responded poorly as far north as Akron, Colo. They have been satisfactory, however, at Archer, Wyo., 100 miles farther north (45).

Because of the great interest in these grasses, resulting from their success in the North, it is considered advisable to report some of the results obtained at Hays, Kans., since 1901. Ten Eyck (67) in 1911 stated that brome-grass was a very hardy grass, resisting both cold and drought, but required a moderate supply of moisture and did not succeed well in a hot climate.

Getty (26) reported in 1921 that none of the tame grasses had proved entirely satisfactory in western Kansas. He concluded that brome-grass was not worth sowing on land that was too dry for alfalfa and was of doubtful value on any land in the western half of Kansas.

Attempts to establish brome-grass in dry-land rotations at Hays have been made annually by the Division of Dry Land Agriculture since 1906. The results of these attempts and of other work conducted by the Division of Forage Crops and Diseases were summarized by Getty (27, pp. 53-54) in 1928:

There is not much chance of sufficient growth to cut for hay after the third year. An attempt to maintain a permanent stand of brome-grass around the laboratory was eventually given up in favor of buffalo grass.

Brome-grass is one of the earliest grasses to start growth in the spring, and an established stand would furnish a few weeks of excellent early pasturage; this possibility, however, does not warrant attempts to grow the crop. While brome-grass is fairly drought-resistant, it suffers too much from heat at Hays. It has been grown by farmers with success farther northeast in Kansas, notably in Washington County.

Brome-grass was grown successfully in hills and cultivated nursery rows at Hays, along with other miscellaneous grasses, for several years, but from an economic standpoint it is a failure under field conditions.

Although crested wheatgrass was tested less extensively than brome-grass, results obtained at Hays from 1929 to 1934 indicate that crested wheatgrass is similar to brome-grass in its susceptibility to hot weather. Dillman (20) reported in 1931 that crested wheatgrass had a higher water requirement than brome-grass.

Aldous and Zahnley (4) report that the successful use of the tame grasses was restricted to about the eastern one-third of Kansas where the annual rainfall averages more than 30 inches. They state, however, that crested wheatgrass may have value in the northwestern part of Kansas. Their report of the successful use of locally adapted seed of brome-grass in Washington County, Kans., indicates the possibility of further improvement in adaptability of the tame grasses by careful selection.

ITALIAN AND PERENNIAL RYEGRASS

Italian and perennial ryegrass, not to be confused with Canada or Virginia wild-rye, have proved to be extremely short-lived, relatively unproductive, and poorly adapted to the drier parts of the

⁶ WILSON, C. P. BROME GRASS AND ALFALFA FOR PASTURE. N. Mex. Agr. Expt. Sta. Press Bull. 835, 2 pp. 1937. [Mimeographed.]

Plains, although they have given satisfactory results where the annual precipitation approaches or exceeds 30 inches. Repeating a report issued in 1894, Griffin (29) states that these grasses were not successful in the Arkansas River Valley in Colorado. Getty (27) also reported consistent failure with these species at Hays, Kans.

SUPPLEMENTARY INFORMATION

Additional information concerning the distribution of native plants species is reported by Gates (24) for Kansas; Cory and Parks (19) for Texas; and the Division of Forage Crops and Diseases, Bureau of Plant Industry,⁷ for 11 locations in the central and southern Great Plains. Parks (50) lists and describes native plants of economic value in Texas, and Cory (18) shows the preference of livestock for different classes of range forage.

GRASS MIXTURES

Seeding a mixture of well-adapted species may result in the following advantages over seedings in pure cultures: More success in obtaining a stand, a greater variety of forage, a longer grazing period by the use of early and late strains, more rapid and complete occupancy of the land by the use of vegetative-spreading species in conjunction with those capable of spreading solely by seed, and rapid growth of some species while others are slowly becoming established. Seeding mixtures of blue grama and bluestem (western wheatgrass) in combination with wide-spaced sodding of buffalo grass offers promising possibilities for medium heavy to heavy soils.

EFFECT OF SOURCE OF SEED

One of the most remarkable revelations of recent testing work with native grasses is the effect of source of seed on growth. Seeds of many species have been obtained from southern Texas and Arizona and from various locations successfully farther north into Montana and North Dakota. When grown at Woodward, Okla., the plants from the most southern locations were decidedly later in flowering but noticeably taller, more vigorous, and produced much more forage than those grown from seed harvested farther north (fig. 19). The growth was successively less and the plants earlier in maturity with each successive northerly acquisition. These results indicate that it is not advisable to use seed from the North if well-adapted local seed is available. They further indicate the possibility of improvement by introducing seed from southern locations, if weaknesses such as susceptibility to drought and cold are not also introduced.

REJUVENATING DEPLETED PASTURES

Native grasslands of the central and southern Great Plains have become seriously depleted in stand, vigor, and carrying capacity as a result of prolonged drought, intense heat, and soil blowing, com-

⁷ SAVAGE, D. A. See footnote 3, p. 2.

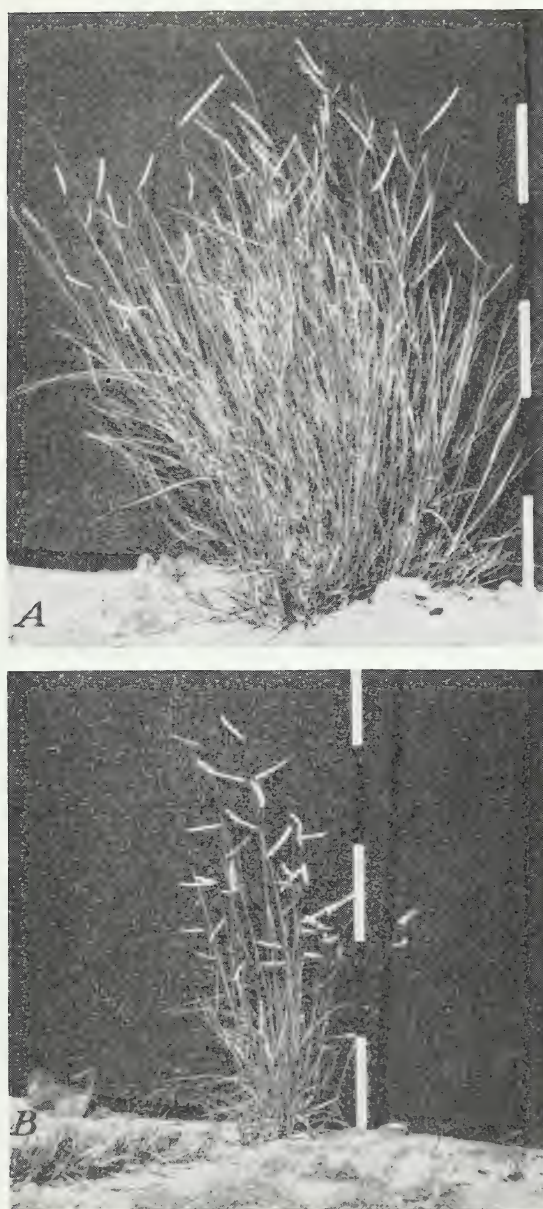


FIGURE 19.—Typical plants of blue grama from New Mexico (*A*) and Montana (*B*), as they appeared at Woodward, Okla., in 1937, showing the effect of source of seed. The bicolored sections on rule are 3 inches long.

bined with overgrazing and untimely grazing often caused by the lack of supplementary forage. Authorities agree that overgrazing has been an important damaging factor on pastures and range land, Evans (21), Hanson et al. (33), Jardine (37), Kirk (40), Sampson (53), and Talbot (66). Results of surveys conducted under different degrees of grazing and nongrazing in 1935 and 1936 (58) and the reports of Weaver and Albertson (70) indicate that the adverse climatic conditions often were equally if not more damaging than close grazing. It is evident, however, that excessive grazing is always detrimental, especially during severe drought.

Reseeding, contour furrowing, shrub eradication, and grazing control have been suggested as methods of improving native pastures badly depleted by adverse climatic conditions and overgrazing. Results of ecological surveys conducted cooperatively by the Division of Forage Crops and Diseases and other State and Federal agencies in the Plains in 1935 (58) and 1936 (60), indicate that most pastures in the region still contain sufficient plants to provide a nucleus for rapid recovery under favorable climatic conditions. Albertson (1) reported that buffalo grass rapidly reclaimed areas bared by drought. A few pastures are so badly denuded or deeply covered by silt that several favorable seasons will be required for recovery to take place. However, it is possible that many of these pastures may be plowed, thinking they are irreparably damaged when in reality most of them will probably recover fairly fast with the advent of better growing conditions.

RESEEDING PASTURES OR RANGE

With certain definite exceptions and limitations, the methods tentatively suggested for use in reseeded cultivated land may be attempted on range pastures. However, artificial reseeded of depleted ranges is much more difficult to accomplish successfully than seeding clean stubble lands. The old surviving plants of grass, shrubs, and associated weeds often offer too much competition to the younger, weaker, and slower growing grass seedlings. Because of these and other adverse conditions including unfavorable weather and the use of unadapted strains, many past attempts to reseed ranges by artificial means have generally resulted in failure. A few notable or partial successes have been experienced. The possibilities have not been fully determined.

In 1897 Williams (72) reported that an excellent pasture was obtained in South Dakota by collecting western wheatgrass and filling in the bare places with it. He reported that an experiment was made at the Kansas (Garden City) Station in 1892. A badly damaged pasture was heavily disked, sown to a mixture of orchard grass, meadow fescue, Kentucky bluegrass, timothy, redtop, clover, and alfalfa, and packed with a surface roller. He stated that the seed germinated quickly and the tame grasses made an excellent start, but that by September the wild grasses had crowded them out. This result is not surprising as all the grasses included in this trial have proved to be poorly adapted to the dry Plains.

Forsling and Dayton (22) concluded in 1931 that artificial range reseeding on western mountain range lands would be successful on areas with rainfall, soil, and other growing conditions above the

average. Their work was confined largely to cultivated species and a few native western range plants; however, they stated that the success with the few native western species suggested that promising results could be attained when more attention is devoted to range plants.

Wilson (74 p. [3]) in 1931 concluded that where there is control of the range many of the New Mexico ranges can be improved by artificial reseeding.

The results so far accomplished indicate that—

chamiza (*Atriplex canescens*), blue grama grass (*Bouteloua gracilis*), and in the colder sections smooth brome grass (*Bromus inermis*), are among the most promising species for artificial reseeding in this State. * * * As a rule, artificial reseeding in this State, especially where there is much vegetation already on the land, requires plowing or similar preparation of the soil before planting. At least one or two cultivations may also be essential during the fore part of the growing season, for weed control. Plot tests and the experience of stockmen indicate that some of the New Mexico ranges can be materially improved, however, merely by broadcasting chamiza or blue grama grass seed, with little or no soil preparation.

The possibility of establishing stands of grass in pasture furrows was first suggested and tested by the Division of Agrostology, now known as the Division of Forage Crops and Diseases, at the old range experiment station at Abilene, Tex., in 1899 by Bentley (6). His conclusions regarding this phase of the studies were (6, pp. 6-7):

Another experiment has been instituted on one of the station pastures that promises to result favorably, namely, catching the grass seeds that are blown about by the winds.

The prevailing winds during the summer months in central Texas are from the south. Many of the grass seeds, as they fall to the ground, except where the surface has been scarified or plowed, are blown by the wind onto other lands. * * * In order to save these seeds to the pastures producing them, a part of one of the station pastures was selected, and about every 12 feet furrows have been plowed from east to west, the idea being, (1) that the seeds falling to the ground, if blown at all by the winds, will be caught in these furrows and in that way saved to the pastures, (2) that the storm waters falling on such pastures, instead of being allowed to waste by running off into creeks and bottoms, will also be caught in the furrows.

This work was done in May, 1899. By June 30 the furrows had caught a great many seeds, and, as the result of surface irrigation incident to the rain having been collected in them, the grass immediately proximate to such furrows was much greener and more vigorous than that farther away. Indeed, in approaching the pasture so treated the furrows could easily be traced by the eye a half mile away by their fresh, green appearance.

This first attempt at pasture furrowing in the Plains was conducted for only a brief period, but it indicated the possibilities of combining artificial reseeding with the control of run-off waters.

A large number of native grasses were seeded in the spring and fall of 1937 on sand and "hard-land" pastures in the vicinity of Woodward, Okla. The seedings were broadcast, close-drilled and in rows, at different depths and rates, on untreated sage land and on land upon which the sage had been grubbed, mowed, and disked. Some of the seedings were protected from, and others were exposed to, grazing. Fair to excellent initial stands were obtained in most instances, but with a very few isolated exceptions, all the spring seedings failed during the summer as a result of extremely severe drought, numerous grasshoppers, and competition from the older plants and associated weeds. In September 1937, 10 species of grass

were sown at Woodward on range pastures on which sagebrush and skunkbrush had been grubbed, disked, mowed on different dates, or untreated, under nongrazing and two degrees of grazing (fig. 20). Dry weather at seeding time delayed emergence until October 5. Six of the more cold-resistant species survived the first killing frost on November 16, remained green most of the winter, and renewed active growth in the spring of 1938. Successful stands of sand lovegrass, turkeyfoot, and prairie beardgrass were obtained in range reseeding trials at Woodward in the spring of 1938.



FIGURE 20.—Drilling grasses on sage-infested range pastures near Woodward, Okla.

No cultivated crop, such as Sudan grass, is suggested for use in preparing range pastures for reseeding. Seeding as early in the spring as warmth and moisture permit appears essential, as weeds cannot be controlled by tillage without damage to old surviving plants of grass. Grasses capable of emerging in cool weather, therefore, have advantages over slower starting strains for range reseeding. In this respect blue grama is handicapped through its delayed emergence until warm weather ensues. Other methods of seeding and of treatment after seeding may be followed in the manner described for cultivated stubble land.

Rodents, such as jack rabbits, prairie dogs, and kangaroo rats, have seriously retarded recovery of overgrazed pastures and hindered efforts at artificial reseeding in parts of the region. Parker^s stated that it was inadvisable to attempt artificial reseeding with grasses or palatable shrubs without accompanying efforts at rodent eradication or control.

^s PARKER, K. W. EFFECT OF JACKRABBITS ON THE RATE OF RECOVERY OF DETERIORATED RANGE LAND. N. Mex. Agr. Expt. Sta. Press Bull. 839, 3 pp. 1938. [Mimeographed.]

PASTURE FURROWING

In connection with resodding studies at Hays, Kans., alternate strips of buffalo grass sod, 4 inches deep and 12 to 17 inches wide, were removed from native pastures for use on cultivated land. This was not done with the object of improving the pasture. However, to prevent erosion, the furrowed strips were removed on the contour as nearly as it was possible to do so without surveying instruments. A limited amount of this work was done from 1910 to 1928 and an extensive amount from 1929 to 1936. The furrows left in the pastures usually were reoccupied with buffalo grass stolons by the end of the first season. However, red three-awn (triple-awn), a comparatively unpalatable, deep-rooted species, also invaded the furrows and persisted for many years. The undercover of buffalo grass in the furrows and immediately adjacent thereto produced slightly more growth and remained green longer than unfurrowed areas. It was not determined if these advantages compensated for the persistence of the weedy red three-awn and the temporary loss of grass during the brief recovery period.

In recent years the Texas Substation No. 7 at Spur reported outstanding improvement of a pasture by contour furrowing. Casual observation indicated that buffalo grass represented nearly 90 percent of the total vegetation on this pasture, which, because of its vigorous spreading habit, may have been partly responsible for the advantages noted. It is reasonable to suppose that results of equal significance may be expected under similar conditions elsewhere in the Plains. However, few pastures in the region, except abandoned fields on heavy soils, possess a vegetative cover composed of such a high percentage of buffalo grass or other species capable of spreading rapidly by vegetative means.

Many types of pasture furrows have been demonstrated for several years by the Soil Conservation Service. Varying degrees of improvement have been indicated by this work, particularly at Cheyenne Wells, Colo., and Mankato, Kans. More extensive research on this problem is needed before final recommendations can be offered.

According to actual measurements made by F. G. Ackerman, of the Soil Conservation Service, and his predecessors at Hays, Kans., soil and water losses are negligible on native pasture land having a slope of 5 percent and a dense, thrifty cover of blue grama and buffalo grass. Under such conditions or when depleted pastures are fully recovered and properly managed, pasture furrowing may not be necessary.

SHRUB ERADICATION

Native pastures on sandy soils in the southern Plains have become thickly infested with a rank growth of sand sagebrush. Although this shrub is slightly palatable as a browse plant during the winter and has kept many grasses from being wholly destroyed by prolonged overgrazing, it is a strong competitor for moisture and, if possible, should be replaced with good grasses. For several years the Division of Dry Land Agriculture conducted mowing, burning, and grubbing experiments for its control at Woodward, Okla.

Preliminary results of this work, supported by chartograph studies of the vegetation on treated and untreated areas, indicated that the shrub could be mowed satisfactorily with an ordinary mowing ma-

chine. Mowing wholly eradicated many of the sage plants, subdued the remainder and rendered them more palatable, and noticeably increased the stand and vigor of the grass. This work was conducted on a moderately grazed pasture and was expanded in 1937 to determine when both sagebrush and skunkbrush may be mowed to best advantage and if elimination of the shrubs under continuous overgrazing is detrimental to the grass (fig. 21).



FIGURE 21.—A, Mowing sand sagebrush on range near Woodward, Okla.; B, close view of vegetation, showing dearth of grass and presence of weeds among the sage.

Clarke and Tisdale (12) report similar results with silver sagebrush in Canada. They state that repeated cutting greatly weakens the plants and eventually kills them.

Grubbing was effective in controlling the sagebrush at Woodward but was too costly, requiring 28 man-hours per acre in heavy infestations. Burning appeared to be equally as damaging to the grass as to the sage. Hanson (32) reports that burning was successful in destroying black sagebrush in Colorado. Several ranchers near Woodward reported success in controlling sand sagebrush by close grazing with sheep and goats.

CONTROL OF PRICKLYPEAR

A comparison of the published statements of Bartlett in 1854 with those of Smith (65) in 1899 indicates rather definitely that cumulative effects of overgrazing and drought since 1885 are responsible for the present serious infestations of pricklypear, mesquite (mesquite bean), sagebrush, and other objectionable plants on range pastures in the region. In reference to a number of specifically described locations in western Texas, Bartlett, as quoted by Smith (65, p. 17), reported as follows:

The whole of this district consists of gently undulating plains, *without timber save along the margins of the streams*, and is covered with the most luxuriant grass. The indigenous prairie grass is tall, coarse, full of seed at the top, and when young resembles wheat in the spring. But in grasses the glory of the State is the mesquite, found only in western Texas. It yields a fine soft sward, preserves its verdure in the winter, and beyond all comparison affords the best wild pasture in the world.

He made practically the same descriptions of other localities, stating that the chaparral only occupied the river valleys, and that beyond them were rolling grass-clad Plains with a few scattering groups of cactus and low mesquite trees.

After carefully examining the same areas in the late nineties, Smith found that the same region was covered with brush and cactus.

Many stockmen who have noted the progress of this pest are of the opinion that in another twenty years prickly pear will cover a large part of the now open or fairly open grazing lands in the southern part of Texas, to the detriment of all stock and land owners (65, pp. 16-17).

This predicted condition has occurred to a surprising degree (fig. 22) in parts of the region, particularly in eastern Colorado.

Nongrazing without other means of control has not been effective in subduing pricklypear, despite the supported assumption that prolonged overgrazing was responsible for the serious inroads of this pest. During the 6 drought years of 1932-37 it increased noticeably on nongrazed plats at Hays, Kans. This may have been due partly to drought which would affect the grasses and forbs much more seriously than the cacti. Grubbing the plants below the crowns and hauling them off the fields have greatly reduced the pricklypear from pastures at Hays, Kans., Akron, Colo., and elsewhere in the region. This operation is laborious in thick infestations but is usually effective, fairly economical, and certainly advisable in controlling light infestations. It should be followed with some protection from grazing to enable the associated grasses to recuperate and reoccupy the scalped areas. Many spined opuntia (manyspine pricklypear) is more diffi-

cult to eradicate by grubbing because its spreading rootstalks are capable of producing new plants at each node, according to Harvey (34).

Smith (65, pp. 16-17) reported in 1899:

Fire is the only remedy which is always effective in fighting the prickly pear, but to develop enough grass and undergrowth so that a fire will run through thickets composed of this cactus requires that cattle shall be kept out of the pastures one and often two years, and few stockmen are willing to sacrifice two years' growth of grass even to rid themselves of the prickly pear. * * * * To be the most effective the pasture should be burned in spring just after the new growth has commenced, because the cactus is then most easily destroyed. The young and tender shoots would be scorched and cooked and prevented from further development, and the singeing off of the spines on the older shoots would expose them to destruction by animals. The fire would also check the development of the weeds and brush that thrive in the shelter of the clumps of cactus. If hogs or goats could be herded on the prickly pear after the fire, the destruction would be much more complete.



FIGURE 22.—Pasture infested with pricklypear (western pricklypear) near Woodward, Okla.

Firing pastures for the control of cacti may be advisable as a last resort in heavy infestations but is certain to be at least temporarily injurious to the grasses in dry localities. After using goats during the clean-up period following the fire, the grasses should be allowed to recuperate by the reduction or exclusion of livestock for indefinite periods.

BROOMWEEDS

Many seriously depleted range pastures on semiheavy to heavy soils of shallow to medium-shallow depths have become heavily infested with annual snakeweed (broomweed) (fig. 23) and broom snakeweed (turpentine weed), the perennial broomweed. The vigorous growth of these unpalatable plants offers strong competition to the grasses and often seriously delays their recovery. Several ranchers obtained satisfactory results in 1937 from mowing the annual broomweed before the seed matured. Recovery was noticeably more rapid on mowed than on

unmowed areas in the vicinity of Woodward following late summer rains in 1937.



FIGURE 23.—Typical infestation of snakeweed on a pasture near Woodward, Okla.

GRAZING CONTROL

All factors considered, some form of grazing management appears to offer the surest means of improving badly damaged pastures. Aldous (3) stated in 1935 that in the western two-thirds of Kansas the restoration of the native vegetation by the application of proper grazing practices is the only satisfactory method to be used in the improvement of pastures. At the Northern Great Plains Field Station, Mandan, N. Dak., the Division of Dry Land Agriculture has determined that deferred and rotation grazing has outstanding advantages over continuous grazing, as reported by Sarvis (54, 55). The cattle gained faster and the grass was maintained in better condition by rotating than by continuously grazing similar areas with the same number of livestock. The rotation pasture was divided into three parts and the cattle rotated spring, summer, and fall in such a manner that the fields received alternate rests in successive years during each part of the growing season. The fields were grazed in the order shown in table 1 during 6 of the years that the investigation was in progress.

TABLE 1.—Grazing program

Period	Fields indicated by letters					
	First year	Second year	Third year	Fourth year	Fifth year	Sixth year
Spring.....	A	B	A	C	C	B
Summer.....	B	A	C	A	B	C
Fall.....	C	C	B	B	A	A

Similar work was conducted by the same Division at Ardmore, S. Dak., but the advantages of rotation grazing were much less apparent, according to Cole and others (17). At Ardmore the rotation pasture was divided into two parts, which did not provide an opportunity for the same degree of advantage in rest periods that is possible by the three-division method. Black and others (7, *pp. 16, 18*) reported as follows in 1937:

Vegetation of the type [short-grass, composed of a high percentage of buffalo grass] making up the pastures at Ardmore is not likely to be damaged if it is not grazed so closely that the animals grazing it suffer severe loss in weight. * * * In the last 3 years of the investigation, steers on pasture alternately grazed made significantly greater gains than steers grazed on pasture continuously at the same rate of stocking.

Grazing investigations of this nature are also in progress at Miles City, Mont., Manyberries, Alberta, and Swift Current, Saskatchewan, but practically no work of this kind has been conducted in the drier parts of the central and southern Great Plains. Some grazing studies are in progress at Manhattan, Kans., Fort Collins, Colo., Sonora, Tex., in eastern Oklahoma, and at the Jornada Experimental Range in southern New Mexico. All of these experiments are conducted outside the so-called dust bowl. Consideration is being given plans to undertake grazing investigations at Woodward, Okla., and on sandy and heavy soils in the "center of the dust bowl" as well as elsewhere in the drier parts of the high plains.

Until more definite information is available, it is suggested that light, deferred, and rotation grazing may be expected to promote recovery on most pastures in the region, especially on sandy or semi-sandy soils where the vegetation is represented in large measure by tall and midtall grasses. The results of range surveys conducted in the central and southern Great Plains in 1935 and 1936 (58) and other work reported by Clements and Weaver (16) indicate that these grasses are damaged more by overgrazing than the short species. Since the results also showed that blue grama responds well to protected grazing and is an important constituent of all "hard-land" pastures, rotation grazing may be adopted as a fairly sound practice on most classes of soil and vegetation in the area. The rotation system employed so advantageously during the growing season at Mandan may be adapted to year-long grazing in the southern Plains. A farmer or rancher may divide his grazing area into two nearly equal parts, if watering facilities permit, saving slightly more than half of the area for continuous winter grazing and dividing the remainder into three equal parts for deferred and rotation grazing during the growing season.

In reference to range improvement on the plains of western Canada, Kirk (40, *p. 30*) states that—

On the dry range lands of the short grass plains * * * over-grazing has been responsible more than any other factor for the depleted condition of certain range areas. It seems clear also that the most economical way of restoring depleted pastures * * * is to protect them during the spring and summer months and then graze them in the fall and winter after the seed has been shed. If the pasture is badly depleted this method of deferred grazing should be adopted for several years in succession.

Clements and Weaver (16) challenged the commonly accepted belief that the short grasses (buffalo grass and blue grama) were al-

ways the dominant species in the drier parts of the Plains. Their studies show that the midtall grasses, such as the wheatgrasses and the needlegrasses, were the original and climax vegetation of the area before the advent of the white man. Clements and Chaney (15) conclude that the pressure of overgrazing and drought has largely replaced the midgrasses with their shorter and hardier associates, leaving what is described as a disclimax of short grass resulting from the disturbing factors noted. This conclusion is supported by the appearance of many of the midgrasses in railroad right-of-ways, cemeteries, and other protected areas.

The presence of the midgrasses under the natural system of rotation grazing practiced by the migrating herds of buffalo in the early days supports the suggestion that deferred and rotation grazing may be expected to improve the variety and production of native pasture vegetation. That the short grasses have long been important constituents of the range cover and should therefore continue to receive careful consideration in pasture improvement studies is attested by the statement of Sage in 1841, quoted by Ghent (28), with reference to the Plains in southern Nebraska, that the immense Plains were generally clad with a short curly grass, very fine and nutritious, and well adapted to the countless herds of buffalo and other wild animals that fed upon it.

SUMMARY

Results of limited grass investigations conducted in the drier parts of the central and southern Great Plains during the past 50 years, together with general observations by various research workers in the region, are reviewed and used as a basis for offering tentative suggestions concerning grass culture and range improvement.

Results of detailed surveys conducted at 11 locations in the region showed that 25 to 40 or more years were required in the past for abandoned farm land to revert naturally to a good stand of native grasses. The present limited acreage of native grassland and its denuded condition indicate that natural revegetation may be expected to proceed at much slower rates in the future.

The processes of natural recovery may be effectively hastened by artificial means, using well-adapted grasses, employing methods of establishment considered most satisfactory at the present time, and taking full advantage of favorable growing seasons.

Clean-tilled land blows so readily that it is considered a poor method of preparation for grass, except where vegetative spreading species are planted in rows and protected by cultivation most of the first season, or where the grasses are seeded in the fall and protected at intervals by lister furrows or wide-spaced rows of Sudan grass.

In most of the region, where soil blowing is severe, close-drilled Sudan grass stubble affords a satisfactory seedbed for perennial pasture grasses. Sorghums also are used for this purpose but are less satisfactory than Sudan grass. Contour listing the land in advance of seeding the preparatory crop is helpful in controlling runoff and erosion. Tillage previous to listing may be advisable to eliminate weeds and store moisture.

The preparatory crop of Sudan grass may be drilled parallel with the lister furrows, either solidly or by leaving an undisturbed furrow

every drill width to assist in controlling run-off and to provide a place for spacing buffalo grass sods in conjunction with seeding other grasses the following year.

Blank listing as a preparation for Sudan grass may be dispensed with where the land is level or very sandy and not susceptible to much loss of water by run-off. In these instances a series of smaller furrows may be obtained at less expense by drilling the Sudan grass in 14- to 20-inch rows with one of the new furrow-type grain drills.

Planting the preparatory crop in wide-spaced lister rows is not advisable because the resultant stubble is seldom sufficient to control soil blowing and properly retard surface evaporation while the seedlings of pasture grasses are slowly becoming well-rooted the following spring.

The preparatory crop of close-drilled Sudan grass usually responds with better stands and more growth when sown at the rate of 15 to 20 pounds per acre in May or June than later in the year. Under favorable conditions Sudan grass may be drilled in late summer on land that has been clean-cultivated throughout the season, but sometimes the crop fails to make sufficient growth for a satisfactory cover, and occasionally it exhausts the subsoil moisture before stopping growth in the fall.

It appears essential to cut Sudan grass before it reaches maturity, leaving a stubble 8 to 12 inches high. This promotes vigorous basal growth and usually provides sufficient stubble and crop residue to prevent soil blowing and reduce surface evaporation while the grass seedlings are emerging and becoming established the following spring.

Spring-sown wheat, oats, barley, or rye may be used to provide noncompetitive surface residue for fall-seeded grasses, although the cover is seldom so effective in controlling blowing and decreasing evaporation as is Sudan grass stubble when grass is planted in the spring.

Grasses may be seeded alone or in mixtures with other grasses much more successfully, on the average, than with nurse crops. A combination of drilling and broadcasting offers possibilities for greater success in obtaining stands of perennial grasses than either method alone.

The optimum depth of seeding most grasses is about 1 inch, with a somewhat shallower depth preferred for small seeds and heavy soils, and deeper planting possible for large seeds and sandy soils.

Suggested seeding rates for blue grama are 5 to 10 pounds to the acre. Bluestem (western wheatgrass) and other species that spread by underground rootstalks or surface runners may be seeded thinner than the bunch grasses, which depend entirely on seed for increase.

Most grasses adapted to the region may be sown to best advantage medium early in the spring, after the danger of killing frost is past, and when winds are less prevalent, temperatures higher, and rainfall more dependable than early in the spring. Cold-resistant species, such as Canada wild-rye, bluestem (western wheatgrass), and Texas bluegrass, respond best to seedings early in the spring or in the fall. Many other grasses may be sown satisfactorily in the fall when moisture conditions are favorable for prompt emergence.

Broadcasting mature hay, containing an abundance of ripe grass seeds, may be adopted as a promising method of seeding until seeds become cheaper in price and more generally available.

Broadcast seedings may be covered with an empty drill. Surface packing after seeding is advisable if sufficient crop residue is present to prevent soil blowing.

Livestock should be excluded during the first growing season and part of the next from areas being reseeded with grass. Limiting the grazing to the winter season for several years would be effective in promoting complete coverage.

Clipping at a height of about 8 inches is advisable in controlling weeds on newly seeded areas.

Blue grama, galleta grass, plains bristlegrass, bluestem (western wheatgrass), side-oats grama, and several other native grasses offer considerable promise for use in revegetation work and may be expected to give best results when seeded in mixtures with each other. On heavy soils it is desirable to seed them in combination with widespread sodding of buffalo grass. A few introduced grasses, particularly weeping lovegrass and a strain of quackgrass, show promise for use under special conditions.

Crested wheatgrass and smooth brome (bromegrass) are poorly adapted to the drier parts of the southern Plains, although they are satisfactory in the foothills of the Rocky Mountains and about 100 miles north of Akron, Colo.

It is not advisable to introduce grass seed from the North, if well adapted local seed is available, although seed from farther south may be used advantageously, if susceptibility to cold and drought are not also introduced.

Reseeding depleted pastures, though more difficult than on cultivated land, may be successful in favorable seasons when adapted seed is sown early in the spring before weeds and other plants start growth. Late fall seedings have been successful when cold-hardy strains were used.

The indications are that contour furrowing offers possibilities for improving pastures by preventing run-off and erosion and providing a place for establishing foundation plants for natural revegetation.

Mowing has been successful in controlling sand sagebrush on native pastures and in improving the growth of associated grasses.

Grubbing pricklypear below the crowns and removing them from the field have effectively controlled this pest. The operation is laborious, but fairly economical and decidedly advisable if performed before the pastures become thickly infested. Firing has been suggested as a means of controlling heavy infestations, but must be preceded and followed by the exclusion of livestock.

Deferred and rotation grazing appears to offer the surest means of improving badly damaged pastures and maintaining them in thrifty condition.

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APPENDIX

TABLE 1.—List of grasses, other forage crops, and pasture shrubs mentioned or described in this circular

Locally recognized common name	Accredited common name with other synonyms in parentheses	Genus and species
Alfalfa.....	Alfalfa.....	<i>Medicago sativa</i> .
Annual broomweed.....	Snakeweed.....	<i>Gutierrezia dracunculoides</i> (DC.) Blake.
Bermuda grass.....	Bermuda grass.....	<i>Cynodon dactylon</i> (L.) Pers.
Big bluestem.....	Bluejoint turkeyfoot (big bluestem).	<i>Andropogon furcatus</i> Muhl.
Black grama.....	Black grama (woolly-foot grama) ..	<i>Bouteloua eriopoda</i> (Torr.) Torr.
Black sagebrush.....	Big sagebrush (black sage or blue sage, and simply sage or sagebrush).	<i>Artemisia tridentata</i> Nutt.
Blowout grass.....	Blowout grass.....	<i>Redfieldia flexuosa</i> (Thurb.) Vasey.
Blue grama.....	Blue grama (white, red, or purple grama).	<i>Bouteloua gracilis</i> (H. B. K.) Lag.
Bromegrass.....	Smooth brome (common brome, Hungarian brome, awnless brome, field brome, Australian brome, and Russian brome).	<i>Bromus inermis</i> Leys.
Buffalo grass.....	Buffalo grass.....	<i>Buchloe dactyloides</i> (Nutt.) Engelm.
Canada wild-rye.....	Canada wild-rye.....	<i>Elymus canadensis</i> L.
Chamiza.....	Fourwing saltbush (chamise, chamiso).	<i>Atriplex canescens</i> (Pursh) Nutt.
Clover.....	Clover (trefoil).....	<i>Trifolium</i> sp.
Crested wheatgrass.....	Crested wheatgrass.....	<i>Agropyron cristatum</i> (L.) Gaertn.
Curly-mesquite.....	Curly-mesquite (southwestern buffalo grass).	<i>Hilaria belangeri</i> (Steud.) Nash.
Galleta grass.....	Galleta (black grama).....	<i>Hilaria jamesii</i> (Torr.) Benth.
Giant reedgrass.....	Giant reedgrass.....	<i>Calamovilfa gigantea</i> (Nutt.) Scribn. and Merr.
Hairy grama.....	Hairy grama.....	<i>Bouteloua hirsuta</i> Lag.
Indian grass.....	Indian grass.....	<i>Sorghastrum nutans</i> (L.) Nash.
Indian ricegrass.....	Indian ricegrass (sandgrass).....	<i>Oryzopsis hymenoides</i> (Roem. and Schult.) Ricker.
Italian ryegrass.....	Italian ryegrass.....	<i>Lolium multiflorum</i> Lam.
Jaragua.....	Jaragua.....	<i>Hyparrhenia rufa</i> (Nees) Stapf.
Kentucky bluegrass.....	Kentucky bluegrass (lawnglass, speargrass, junegrass, green-sward (meadow grass in England)).	<i>Poa pratensis</i> L.
Lehmann lovegrass.....	Prairie beardgrass (little bluestem, broom beardgrass, broomsedge, and small feathergrass).	<i>Eragrostis lehmanniana</i> Nees.
Little bluestem.....	Many-spined opuntia.....	<i>Andropogon scoparius</i> Michx.
Manyspine prickly-pear.....	Meadow fescue (English bluegrass).	<i>Opuntia polyacantha</i> Haw.
Meadow fescue.....	Mesquite.....	<i>Festuca elatior</i> L.
Mesquite bean.....	Needlegrasses.....	<i>Prosopis</i> spp.
Needlegrasses.....	Orchard grass.....	<i>Stipa</i> spp.
Orchard grass.....	Perennial ryegrass (English ryegrass).	<i>Dactylis glomerata</i> L.
Perennial ryegrass.....	Plains bristlegrass (perennial fox-tail).	<i>Lolium perenne</i> L.
Plains bristlegrass.....	Quackgrass (couch grass and quitch grass).	<i>Setaria macrostachya</i> H. B. K.
Quackgrass.....	Red three-awn (triple-awn dog-town grass, long-awned needlegrass, prairie three-awn, long-needle three-awn, and wire needlegrass).	<i>Agropyron repens</i> (L.) Beauv.
Red three-awn.....	Redtop.....	<i>Aristida longiseta</i> Steud. ¹
Redtop.....	Ringgrass (Ringmuhly), and ticklegrass.	<i>Agrostis alba</i> L.
Rough rush grass.....	Rough rush grass.....	<i>Muhlenbergia torreyi</i> (Kunth) Hitchc.
Sand bluestem.....	Turkeyfoot (sand bluestem).	<i>Sporobolus asper</i> (Michx.) Kunth.
Sand dropseed.....	Sand dropseed.....	<i>Andropogon hallii</i> Hack.
Sand lovegrass.....	Prairie sandgrass (long-leaved reedgrass and sandreed).	<i>Sporobolus cryptandrus</i> (Torr.) A. Gray.
Sand paspalum.....	Sand sagebrush.....	<i>Eragrostis trichodes</i> (Nutt.) Nash.
Sand reedgrass.....	Silver beardgrass.....	<i>Paspalum stramineum</i> Nash.
Sand sagebrush.....	Hoary sagebrush.....	<i>Calamovilfa longifolia</i> (Hook.) Scribn.
Silver beardgrass.....	Side-oats grama (tall grama).....	<i>Artemisia filifolia</i> Torr.
Silver sagebrush.....		<i>Andropogon saccharoides</i> Swartz.
Side-oats grama.....		<i>Artemisia cana</i> Pursh.
		<i>Bouteloua curtipendula</i> (Michx.) Torr.

¹ *Aristida longiseta* and *A. purpurea* Nutt. are both considered when mention is made of red three-awn (triple-awn), no attempt being made to distinguish between these closely related species.

TABLE 1.—List of grasses, other forage crops, and pasture shrubs mentioned or described in this circular—Continued

Locally recognized common name	Accredited common name with other synonyms in parentheses	Genus and species
Skunkbrush.....	Skunkbush (squawberry, squawbush, skunkbrush, lemita, lemonade sumac, polecat bush, shoneehaw, and three-lobed sumac; also ill-scented sumac).	<i>Rhus trilobata</i> Nutt.
Sorghum.....	Sorghum.....	<i>Sorghum vulgare</i> Pers.
Sudan grass.....	Sudan grass.....	<i>Sorghum vulgare</i> var. <i>sudanense</i> (Piper) Hitchc.
Sweetclover.....	Sweetclover.....	<i>Melilotus</i> spp.
Switchgrass.....	Switchgrass.....	<i>Panicum virgatum</i> L.
Texas bluegrass.....	Texas bluegrass (plains bluegrass).	<i>Poa arachnifera</i> Torr.
Timothy.....	Timothy.....	<i>Phleum pratense</i> L.
Turpentine weed.....	Broom snakeweed (perennial broomweed, broomweed, matchweed, turpentine-weed, and yellow top).	<i>Gutierrezia sarothrae</i> (Pursh) Britt. and Rusby.
Vine-mesquite.....	Vine-mesquite (grapevine-mesquite, vine panicgrass, ricegrass, vine grass, and wire grass).	<i>Panicum obtusum</i> H. B. K.
Virginia wild-rye.....	Virginia wild-rye.....	<i>Elymus virginicus</i> L.
Weeping lovegrass.....	Pricklypear.....	<i>Eragrostis curvula</i> (Schrud.) Nees.
Western pricklypear.....	Bluestem (bluejoint, Colorado bluestem, Smith blue-joint, western wheatgrass).	<i>Opuntia humifusa</i> Raf.
Western wheatgrass.....	Dropseed.....	<i>Agropyron smithii</i> Rydb.
.....	<i>Agropyron</i> spp.
.....	<i>Agropyron pungens</i> (Pers.) Roem. and Schult.
.....	<i>Eragrostis secundiflora</i> Presl.
.....	<i>Sporobolus fimbriatus</i> Nees.

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This circular is a contribution from

<i>Bureau of Plant Industry</i> -----	E. C. AUCHTER, <i>Chief.</i>
<i>Division of Forage Crops and Diseases</i> ---	P. V. CARDON, <i>Principal Agronomist, in Charge.</i>

